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ABSTRACT

Teams of teachers, other science educators, and scientists selected from a national search for project writers have proposed using the following set of questions to guide the inclusion of earth science content into the kindergarten through grade 12 curriculum. The Essential Questions are organized in a K-12 sequence by six content areas: (1) Solid Earth (lithosphere); (2) Water (hydrosphere); (3) Air (atmosphere); (4) Ice (cryosphere); (5) Life (biosphere); and (6) Earth in Space. The questions have been developed within the context of the goals for earth science literacy as reported in Earth Science Education for the 21st Century: A Planning Guide, American Geological Institute, 1991. These goals state that for all students to become literate in science and in earth science they need to become stewards of the Earth; develop a deep aesthetic appreciation of the history, beauty, simplicity, and complexity of the Earth; understand ways in which earth scientists investigate the Earth; and understand essential earth science concepts, including geologic time, evolution, change, scales, cycles, and resources. The Essential Questions are organized in a manner intended to guide the sequential development of concepts and subconcepts within each grade level. The Essential Questions in the first section of this report, and the background notes of Key Ideas and Seeking Answers provided in the second section, represent one way to frame the diverse content of earth science. (KR)

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# *Earth Science Content Guidelines Grades K-12*

Funded by a grant from the National Science Foundation

*National Center for Earth Science Education*
*American Geological Institute*
Alexandria, Virginia

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# *Introduction*

Teams of teachers, other science educators, and scientists selected from a national search for project writers have proposed using the following set of questions to guide the inclusion of earth science content into the kindergarten through grade 12 curriculum.

The writing teams were selected to work in grade level groupings: K-3, 3-6, 6-9, and 9-12. These groupings, similar to those used in modern curriculum guides and frameworks, are based on such factors as student development and school organization, for example, lower and upper elementary, middle/junior high, and senior high school.

The Essential Questions are organized in a K-12 sequence by six content areas: Solid Earth (lithosphere), Water (hydrosphere), Air (atmosphere), Ice (cryosphere), Life (biosphere), and Earth in Space. The content organization represents the interacting systems that make Earth unique within the Solar System.

The questions have been developed within the context of the goals for earth science literacy as reported in *Earth Science Education for the 21st Century: A Planning Guide*, American Geological Institute, 1991. These goals, developed by a consensus-building process, state that for all students to become literate in science and in earth science they need to

- Become stewards of the Earth. Stewardship means making informed decisions about using the Earth's resources and maintaining a high-quality environment.
- Develop a deep aesthetic appreciation of the history, beauty, simplicity, and complexity of the Earth.
- Understand ways in which earth scientists investigate the Earth.
- Understand essential earth science concepts including geologic time, evolution, change, scales, cycles, and resources.

Essential Questions integrate these goals into each of the six content areas. For example, the section on Solid Earth includes the following: How can we use soil? (K-3); What problems are caused by using resources? (3-6); What can I do to conserve Earth resources? (6-9); and How does law influence use of the land? (9-12). Seeking answers to these questions leads to stewardship and appreciation of the Earth. It also leads to an understanding of how humans depend on Earth resources; how long it takes the Earth to provide resources that are not renewable within our lifetime; and how we change our environment.

Questions are considered essential if they address the goals stated above

and if they make connections between the students' world and essential concepts in earth science. Questions are essential if they are appropriate to ask at each grade level. They are even more appropriate if students are likely to ask questions themselves.

Essential Questions are listed with a letter (e.g., A., B., C.) and are generally divided into numbered subquestions (e.g., A.1., A.2.). This organization, from a broad question to a series of subquestions under the broad question, is intended to guide the sequential development of concepts and subconcepts within each grade level. For example, in Water, grade level 3-6, question E asks, Why do we need to be increasingly concerned about Earth's water resources? This broad question evokes a wide range of potential content, and the subquestions provide the framework for delineating that content.

The first subquestion (question E.1.) asks, Where does drinking water come from? This type of question is a reasonable starting point for inquiry, since it enables the teacher to draw upon experiences from the students' world. A student observes water coming out of the faucet at home and at school. The teacher could connect this student experience to earth science concepts, such as fresh water sources above and below ground.

The remaining subquestions under question E. ask the student, Where does waste water go?; How do our activities affect water?; What can be done to provide cleaner water in the future?; and Who owns Earth's water? Investigating these subquestions can provide an understanding of the following concepts: waste water may be treated, but it is not destroyed; waste water will eventually evaporate or flow into the ground and to the oceans; industrial, agricultural, and public uses affect water quality; depletion of aquifers without recharging them reduces water quantity; wise use of water resources will provide clean water in the future; and laws can affect the ways water can be obtained and used.

The questions are integrated across the K-12 curriculum, building a hierarchy of ideas from simple to complex. Some questions are repeated in some form at different grade levels. This repetition encourages investigating certain key concepts at later stages of student development. Questions at the K-3 level focus on the students' immediate surroundings at home and in school and encourage teachers to use many activities. At the 3-6 level, the questions focus on the students' expanding perception of their world and their ability to observe and describe earth science objects and events. In grades K-6, teachers should integrate earth science with other subjects, such as language arts, social studies, health, and mathematics.

Grade level 6-9 bridges the observational earth science of the primary grades to the more academic, analytical studies of high school and beyond. In grades 8 and 9, earth science is commonly taught as a one- or two-semester course. By grades 9-12, students are capable of the most rigorous and comprehensive treatment of the interrelationships among the Earth's systems. Because these students are making decisions about education or employment after high school, questions are included that encourage students to explore how knowledge of earth science is used by people in many areas of employment.

The Essential Questions in the first section of this report, and the background notes of Key Ideas and Seeking Answers provided in the second section, represent one way to frame the diverse content of earth science. It is the intent of the National Center for Earth Science Education of the American Geological Institute that this report serve as a working document to stimulate further discussion and experimentation to improve precollege earth science education. To purchase additional copies, contact the AGI Publications Center, P.O. Box 2010, Annapolis Junction, MD 20701, (301) 953-1744.

# *Essential Questions in Earth Science*

## *Solid Earth*

### *K-3*

A. What is the Earth made of?
   1. What is soil?
   2. How are rocks alike and different?
   3. How is the land different from place to place?

B. What causes the land to change?
   1. What can cause big rocks to become smaller?
   2. How are rocks and soil moved from place to place?

C. How can we use materials from the Earth?
   1. What materials can we use from the Earth?
   2. How can we use soil?

### *3-6*

A. What evidence do we have that the inside of the Earth is different from the outside?
   1. What is the Earth's crust made of?
   2. How can we investigate what the Earth's interior is made of?

B. What changes the Earth's surface?
   1. How is the Earth's surface being worn away?
   2. How is the Earth's surface being built up?
   3. In what ways does the Earth's crust move?
   4. How do we know that the continents have moved?

C. How do rocks form?
   1. What happens to melted rock when it cools?
   2. How can sediments become rock?
   3. How can rocks be changed?
   4. What materials that we use come from rocks?

D. What is soil and where does it come from?
   1. How do rocks become soil?
   2. How deep is soil?
   3. How does soil change with depth below the surface?
   4. How do we use soil?

E. What can we learn about geologic history by studying sedimentary rock?

F. Why do we need to be increasingly concerned about the Earth?
   1. How can we run out of a resource?
   2. What problems are caused by using resources?

## *Solid Earth*

### *6-9*

A. How can we model the Earth's surface and its interior?
   1. How do we describe what we see around us?
   2. How do we know where we are on the Earth?
   3. How do we know the Earth's size and shape?
   4. How deep have we penetrated the Earth?
   5. How can we learn about the Earth's interior?

B. How can we investigate rocks and minerals?
   1. What are rocks made of?
   2. How do rocks form?

C. How is the Earth's surface wearing down?
   1. How do rocks break down?
   2. What happens to weathered rock?
   3. How is weathered rock moved?
   4. Where does weathered rock go?

D. Why do we still have mountains?
   1. What makes mountains?
   2. Where are mountains found on the Earth?
   3. How can we explain the global pattern of mountains?

E. How old is the Earth?
   1. What can we learn from layers of rock about the Earth's age?
   2. What methods can we use to measure the Earth's age?

F. How do we use Earth resources?
   1. What Earth resources do we need, and why do we need them?
   2. Where do we find Earth resources that we need?
   3. Why are Earth resources limited?
   4. What can I do to conserve Earth resources?

### *9-12*

A. How do we use the lithosphere?
   1. How and where do we get energy from the solid Earth?
   2. What solid Earth materials do we use, and where do we find them?
   3. How does the lithosphere influence agricultural production?
   4. What are the advantages and disadvantages of using the Earth's resources?
   5. How does law influence use of the land?

B. What is the solid Earth?
   1. How do we measure the Earth's dimensions?
   2. How can we determine the Earth's composition and structure?

C. What clues do rocks and minerals give us about how they were formed?
   1. How do rocks and minerals form?
   2. How do rocks undergo change?

D. How do rocks help us determine the Earth's age?
   1. How can we use the relative dating method to determine sequences of geologic events?
   2. How can we use numerical dating techniques to determine rates of geologic change?

E. How is the Earth's crust moving?
   1. What is the theory of plate tectonics?
      a. How do we know that lithospheric plates move?
      b. How do crustal and mantle processes relate to plate tectonics?
      c. How do crustal features relate to plate tectonics?
   2. How does the Earth's crust adjust to changes in load?

F. How do we recognize landforms produced by constructional processes?

G. How do we recognize landforms produced by degradational processes?

H. How do we depict the Earth's surface and subsurface?
   1. How do we use maps to study the Earth's surface and subsurface?
   2. In addition to maps, what other tools and technologies are used to study the Earth's surface and subsurface?

I. Why are some areas of the Earth's surface considered hazardous for use?

J. What careers are available in the study of the solid Earth, and what other types of employment require knowledge of this discipline?

# *Water* *K-3*

A. What are the different forms of water?
   1. What are some properties of liquid water?
   2. What are some properties of solid water?
   3. What are some properties of water vapor?
   4. What is a cloud?
   5. Where do we find water?

B. How can we use water?

C. What is the difference between clean and dirty water?
   1. What is dirty water?
   2. What can cause water pollution?
   3. How can we conserve water?

*3-6*

A. Why is water special?
   1. What properties make water special?
   2. Why is water necessary in our lives?

B. Where is water found?
   1. Where is water found in the air?
   2. Where is water found on the surface of the Earth?
   3. What clues do we have that water is in the ground?

C. How does water move from place to place?

D. How does water cause changes on the Earth?
   1. How does moving water change the Earth's surface?
   2. What difference does the amount of water make in an environment?

E. Why do we need to be increasingly concerned about Earth's water resources?
   1. Where does drinking water come from?
   2. Where does waste water go?
   3. How do our activities affect water?
   4. What can be done to provide cleaner water in the future?
   5. Who owns Earth's water?

*6-9*

A. How do the waters of the Earth circulate?
   1. Where do we find water?
   2. How does water enter the atmosphere?
   3. How does water come out of the atmosphere?
   4. How does water flow over the land?
   5. How does water move through the ground?

B. How can we investigate the oceans?
   1. Why are oceans salty?
   2. How do ocean waters change with depth?
   3. What makes ocean waters move?
   4. How does water motion in the oceans affect us?

C. How can we use water more wisely?
   1. How do we use water?
   2. Where does the water we use come from?
   3. How does water change when we use it?
   4. What can we do about harmful changes to water quality?

***9-12***

A. What is the water cycle?
   1. How does water change in the water cycle?
   2. How is new water introduced into the water cycle?

B. Why are the oceans important?
   1. How do oceans affect weather and climate?
   2. How do oceans affect the land?
   3. How do oceans affect the composition of the atmosphere?
   4. What resources were formed by ancient oceans?
   5. What resources do present-day oceans provide?
   6. How does human activity affect oceans?

C. What are the characteristics of subsurface water?
   1. How is subsurface water stored?
   2. What controls the movement and rate of movement of subsurface water?
   3. How can subsurface water reach the surface?
   4. What controls the quality, quantity, and availability of subsurface water?
   5. How does subsurface water influence human activity?
   6. How does human activity affect subsurface water?

D. How is surface water distributed?
   1. How does precipitation influence the occurrence of surface waters?
   2. How do streams and lakes change through time?
   3. How are surface and subsurface water related?
   4. What are the effects of moving surface water?
      a. How does moving surface water modify the landscape?
      b. How can moving surface water be used to produce energy?
   5. How does surface water influence human activity?
   6. How does human activity affect surface water?

E. How do laws affect our use of water?

F. What hazards are associated with water, and how can we mitigate them?

G. What kinds of technology are used to study the hydrosphere?

H. What careers are available in the study of the hydrosphere, and what other types of employment require knowledge of this discipline?

# *Air* *K-3*

A. How does weather change?
1. What is today's weather?
2. How does weather change from day to day?
3. How does weather change from season to season?

B. How does weather affect us?
1. How does weather affect our activities?
2. How should we dress for different weather?
3. How does weather affect the way we design our homes?
4. How do we protect ourselves from weather?

C. What is air pollution?
1. What is in air to make it dirty?
2. What causes air pollution?

## *3-6*

A. What is special about the air?
1. What do our senses tell us about the air?
2. What is air made of?
3. What needs air?

B. How does weather change?
1. How do we know when weather changes?
2. How can we measure changing weather conditions?
3. What effect does sunlight have on weather?
4. What effect do mountains have on weather?
5. What effect do oceans have on weather?
6. How do changes in the seasons affect weather?

C. What can we learn from weather records?
1. What can be learned from weather records where we live?
2. What can be learned from weather patterns of various regions?

D. Why do we need to be increasingly concerned about the Earth's atmosphere?
1. Why do we need clean air?
2. What can be done to provide cleaner air?
3. What is the greenhouse effect?

## *6-9*

A. How can we describe the atmosphere?
1. What is air made of?
2. How does the atmosphere change with altitude?

B. Why does weather change?
1. How does weather affect us?
2. How can we observe weather?
3. How can we display weather data?
4. What causes weather to change?
5. How can we predict changes in weather?
6. Why does weather change with the seasons?

C. How can we investigate climate?
1. How is climate different from weather?
2. How does climate change from place to place?
3. What evidence is there that climate has changed through time?

D. How can the atmosphere be changed?
1. How is the atmosphere changed by natural events?
2. How do we change the atmosphere?

***9-12***

A. What are the characteristics of the atmosphere?
   1. What is the composition of the atmosphere, and what energy exchanges take place there?
   2. What is the importance of the atmosphere's layers?
   3. How do Earth and life cycles affect the atmosphere's composition?

B. What is weather?
   1. How is water in the atmosphere related to weather?
   2. What do different types of clouds indicate about weather?
   3. Where and how do low and high pressure areas develop, and what makes them rotate and travel across the Earth's surface?
      a. What makes the wind blow?
      b. What changes occur at weather fronts?
      c. How do geographic regions and geomorphic features affect the development of pressure systems?
   4. How are weather forecasts prepared and used?
   5. What are atmospheric hazards?
      a. Under what circumstances do atmospheric hazards develop?
      b. How can we protect ourselves from atmospheric hazards?

C. What is air quality?
   1. What affects air quality?
   2. What are inversions?
   3. How can we measure air quality?
   4. How can we improve air quality?

D. How do we investigate climate?
   1. How are climate zones similar and different?
   2. How does climate control the geographic distribution of vegetation?

E. What careers are available in the study of the atmosphere, and what other types of employment require knowledge of this discipline?

# *Ice* *K-3*

A. Where do we find most of the Earth's ice?

### *3-6*

A. What are the characteristics of ice?
   1. What happens when water freezes?
   2. How does ice form?

B. What are glaciers?
   1. Where are glaciers found?
   2. How do glaciers affect the Earth?
   3. How do icebergs form?

C. What were the ice ages?

### *6-9*

A. How does ice occur on Earth?
   1. Where is ice found?
   2. What forms does ice take?

B. How can we investigate glaciers?
   1. How do glaciers form?
   2. How do glaciers move?

C. How do glaciers change the Earth?
   1. What happens when a glacier advances?
   2. What happens when a glacier melts?
   3. What is the evidence that ice ages have occurred?

D. What resources result from glaciation?

### *9-12*

A. How does year-round ice affect the Earth's surface?
   1. What causes ice to flow?
   2. How does the movement of glaciers affect the surface over which they flow?
   3. What are some surface effects of permafrost?

B. How can the cryosphere change over time?
   1. What would cause the amount of year-round ice to decrease or increase?
   2. How might human activity affect the cryosphere?

C. How did the most recent ice age affect the Earth?
   1. How did the most recent ice age modify the Earth's topography and drainage?
   2. How did the most recent ice age affect the types and distribution of life?
   3. What resources resulted from the most recent ice age?

D. How can we learn about past climates by studying year-round ice?

E. How and by whom should Antarctica be managed?

F. What hazards are associated with the cryosphere?

G. What kinds of technology are used to study the cryosphere?

H. What careers are available in the study of the cryosphere, and what other types of employment require knowledge of this discipline?

## *Life* K-3

A. What clues do we have that plants and animals lived long ago?
   1. What are fossils?
   2. What were dinosaurs, and what happened to them?

### *3-6*

A. How does life use the Earth?
   1. What is necessary for life on Earth?
   2. How is the Earth used by humans?

B. Why have some living things become extinct during prehistoric and historic times?

C. How do we affect the habitat of other living things?

D. What actions can we take to show concern for life on Earth?

### *6-9*

A. How does the Earth support life?
   1. What materials and conditions support life on Earth?
   2. Why isn't life the same everywhere?

B. How have life and the Earth changed?
   1. How do we know living things have changed through time?
   2. How can fossils reveal the past?
   3. How have living things changed the Earth?
   4. How does the way we live affect living things?

### *9-12*

A. What do fossils reveal about the past?
   1. How do fossils reveal information about the environment in which the organisms lived?
   2. What do fossils reveal about major geographic and environmental changes throughout geologic history?
   3. How do fossils provide evidence for organic evolution?

B. How do Earth materials support food webs?

C. How are we responsible for all remaining living things?

D. How has technology enabled us to extend our habitable environment?

E. What careers are available in the study of the Earth's interaction with the biosphere, and what other types of employment require knowledge of this discipline?

# *Earth in Space*

## *K-3*

A. How are the Earth, Moon, and Sun alike and different?
   1. How does the Sun's position change during the day?
   2. What causes day and night?
   3. What can we see in the day sky and in the night sky?
   4. How does the Moon appear to change?

## *3-6*

A. What can we see in the sky?
   1. What can we see in the day sky?
   2. How does the Sun appear to move in the sky?
   3. What can we see in the night sky?
   4. How does the night sky change?

B. How are the Earth, Moon, and Sun related?
   1. How can the sizes of the Earth, Moon, and Sun be compared?
   2. In what ways do the Earth and Moon move in relation to the Sun?
   3. Why is the Sun considered the Earth's most important energy source?

C. How is the Earth-Moon-Sun system related to other objects in the Solar System?
   1. What are the members of the Solar System?
   2. Where are the Earth, Moon, and Sun located in the Solar System?

D. What can we learn from space exploration?
   1. What have we learned about the Earth and Moon from space?
   2. What benefits to humanity result from space exploration?
   3. How do we learn about the Solar System?
   4. What have we learned about the Solar System from space exploration?
   5. What are the possibilities for life on other planets?

## *6-9*

A. How can we observe objects in the sky?
   1. What can we see without a telescope?
   2. What can we see with a telescope?
   3. How can we observe objects in the sky in other ways?

B. What are the motions of objects we see in the sky?
   1. How do celestial objects move through the sky?
   2. Why do celestial objects appear to move around the Earth?
   3. How do actual motions of objects in the Solar System affect us?

C. What kinds of objects exist in space?
   1. What is the Sun?
   2. How do changes on the Sun affect us?
   3. How does the Earth compare with other objects in the Solar System?
   4. What kinds of objects exist outside the Solar System?

D. How can we use space?
   1. How can we live in space?
   2. What can we learn about the Earth from space?
   3. How has space technology changed our lives?

E. How is the Universe changing?
   1. How did the Universe begin?
   2. How can we measure the Universe?
   3. Will the Universe end?

## *Earth in Space*

### *9-12*

A. What is the setting of the Earth in the Solar System?
   1. What objects are in the Solar System?
   2. Why is the Earth unique compared with other Solar System objects?
   3. How and when was the Solar System formed?

B. What is the setting of the Solar System in the Universe?
   1. How far apart are objects in space?
   2. How does the Solar System move relative to the Milky Way galaxy?
   3. How can we look backward in time by looking into space?
   4. What is the probability that life exists elsewhere in the Universe?
   5. How can people live beyond the Earth's atmosphere?
   6. How is the Universe changing?

C. What tools and technology can we use to extend our senses to study space?

D. What careers are available in the study of the Earth and the Solar System, and what other types of employment require knowledge of this discipline?

# *Essential Questions Key Ideas Seeking Answers*

The following section contains background notes submitted by the K-3, 3-6, 6-9, and 9-12 writing teams. As they developed the Essential Questions, the writers considered which ideas teachers might want their students to understand, and what teachers might do to have students acquire that understanding. Thus, the writing teams' notes about student understanding fill the Key Ideas column, and their notes about teaching strategies form Seeking Answers. Most Essential Questions are developed with related subquestions. In these cases, the information in the Key Ideas and Seeking Answers columns is entered next to the subquestions and not the broad question. This information is provided to guide the reader to the type of earth science content that could be appropriate for inclusion in the K-12 curriculum. To be considered a complete K-12 earth science syllabus would require further development.

It is not intended that students memorize the vocabulary contained in this report, although a teacher may elect to use it in context during investigation and discussion. For example, in Solid Earth, Grades 6-9, Essential Question B.2. asks, How do rocks form? The text in the Key Ideas column includes such terms as crystallization, precipitation, and deformation. These terms are intended for the reader of this report — a teacher or other professional making curriculum and instruction decisions. However, the ideas of crystal growth, formation of limestone by precipitation of calcium carbonate, and alteration of the crystalline structure of rocks by heat and pressure are considered appropriate for students to investigate and understand in grade level 6-9.

In this report, *solid Earth* (lithosphere) refers to the solid portion of the Earth, as compared to the atmosphere and the hydrosphere. Thus, *solid Earth* includes the rocky planetary surface and subsurface, and the rock-forming materials of the planet's interior. *Ice* (cryosphere) refers to both the part of the Earth's surface that is perennially frozen and the zone of the Earth where ice and frozen ground are formed. Objects in this zone include snow, permafrost, glaciers, and floating ice (icebergs).

*Earth materials* is a commonly used term for solid Earth materials, such as soil, minerals, and rocks. *Earth resources* is used in two ways. In the Solid Earth section, the term means Earth materials with some commercial value, for example, metallic and non-metallic minerals, and fossil fuels. In the broader sense, Earth resources include renewable and non-renewable resources, for example, clean water and air, soil, rain forests, and energy sources such as wood, water, wind, animal and plant waste, and fossil fuels.

# *Solid Earth*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| A. What is the Earth made of?<br>1. What is soil? | Soil is made of many different materials. Soil is made of different-sized materials. Soils differ from place to place. | Collect samples of soil from different areas near the school, and bring back into the classroom. Describe and compare samples by touch, sight, and smell (e.g., texture, color). Draw pictures. Use a magnifying glass to examine the samples again, and describe them. What things do you find in the soil? Compare soils from home with those from school. Describe the difference in size, texture, and color of the soil particles.<br><br>See what happens when you add water to one of the soil samples. Put several drops of water into a container with a tablespoon of soil. Then compare wet and dry soils. Use potting soil and sandbox soil. Compare texture, size, and color.<br><br>Place one teaspoon of each soil sample into a glass of water (don't stir). Observe and explain what happens. |
| 2. How are rocks alike and different? | Rocks are composed of different materials having different properties. | Study how you can classify rocks. Ask students to bring in rocks. Supplement with teacher's collection. Sort the rocks on the basis of color, size, shape, texture, and weight (heavy or light). Look at rocks with a magnifying glass, and classify into groups. Report how you classified them.<br><br>Collect a handful of gravel, and sort the gravel into groups.<br><br>Describe how rocks are different from non-rocks. Examples of non-rocks are sand, brick, and wood. |
| 3. How is the land different from place to place? | The surface of the land varies from place to place and may be barren, | Develop a list from students' brainstorming as to what land looks like. |

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| | have vegetation, or be covered by man-made materials. The surface may have mountains, hills, plains, rivers, lakes, towns, and cities. | Have students draw a picture and write a story about their favorite place. Classify the pictures of the different landscapes.<br><br>Provide trays of wet sand for students to build their own landscape. Have students compare their individual trays. |
| B. What causes the land to change?<br>1. What can cause big rocks to become smaller? | Big rocks can be broken into smaller rocks by physical processes. | Describe sandstone, and look at it with a magnifying glass.<br><br>Rub two pieces of sandstone together over black construction paper. Examine the rubbed areas with a magnifying glass. Look at the pieces on the construction paper. Compare the pieces with one another and with the original pieces of sandstone.<br><br>Crush rock salt with a small hammer on black construction paper. Use a magnifying glass to compare the pieces on the paper with one another and with the original piece of rock salt.<br><br>Place chalk in water overnight, and examine what happens to the chalk. Describe how the chalk changes.<br><br>Freeze a piece of porous sandstone that has been soaked in water overnight. Examine what happened. |
| 2. How are rocks and soil moved from place to place? | Water can move rocks and soil to different places. Wind and ice can also move materials from one place to another. | Demonstrate how water can move earth materials. Use a tray (flat planting trays, aluminum roasting pans) with a mixture of sand and gravel. Build a landscape at one end of the tray. Set one end of the tray on a brick or book at an angle, with the landscape at the top of the tray. Pour water onto the landscape. Observe and describe the changes. |

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| | | Visit a stream, beach, or steep slope to observe soil and rock movement. Describe and draw. |
| | | Chart areas of problem drainage on the playground during the school year. |
| | | Demonstrate how wind can move earth materials. Repeat the setup for the experiment that used a tray and mixture of sand and gravel. Use fan instead of water. Observe and describe the changes. Compare these to the observations made for water. Demonstrate how melting ice on a sloped surface can move sediment. |
| C. How can we use materials from the Earth? | | |
| 1. What materials can we use from the Earth? | The Earth is the source of all materials that we use. Some of these materials are soil, sand, gravel, oil, gas, and coal. There is a limited supply of many of these materials. We can reuse some of these materials. | Brainstorm and make a list of some of the materials in your classroom. Classify them according to how they are derived from the Earth. For example, some classroom materials can be classified as paper, glass, metals, and plastics. Discuss how these processed materials originate from earth materials. Discuss how some things that we throw away can be used again by recycling them at home or elsewhere. |
| | We are responsible for taking care of the Earth. | Collect litter at the school playground or nearby location. Sort the litter into different categories, such as plastics, metals, and paper. Discuss who is responsible for putting the litter on the playground and for cleaning it up. |
| | | Categorize the waste material collected over the period of a week in your classroom. Discuss where most of these materials come from and how they can be used more wisely. |

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| 2. How can we use soil? | Soil is used to grow plants and food. | Brainstorm the uses of soil. List might include growing plants, food, and trees; and farming. Consider ways that soil might be lost and how its loss might be stopped. |
| ***3-6*** | | |
| A. What evidence do we have that the inside of the Earth is different from the outside? | | |
| 1. What is the Earth's crust made of? | Earth's crustal materials include rocks, minerals, and soil. Humans and other forms of life live on the Earth's crust. | Investigate local areas. Compare samples of the Earth's crust from other areas collected by instructor. Examine rocks, minerals, and soils from students' yards. |
| 2. How can we investigate what the Earth's interior is made of? | The Earth's interior is investigated directly by digging, drilling, and by studying volcanoes. The Earth's interior is investigated indirectly by inference. Seismic waves generated by earthquakes and by scientists are used to investigate indirectly the Earth's interior. | Do inference activities with black box or clay sphere. Material is placed in the box or sphere. Properties of the model's interior, such as density and magnetism, are investigated indirectly. Read about seismic studies as an example of inference in learning about the Earth's interior. |
| B. What changes the Earth's surface? | | |
| 1. How is the Earth's surface being worn away? | The Earth's surface is worn away through weathering and erosion. These processes tend to level the Earth's surface by transporting sediments to lower elevations and depositing them in layers. | Investigate chemical weathering of limestone by placing it in vinegar. Freeze porous sandstone saturated with water, and observe changes caused by freezing. Observe and describe various sediments. Do stream table activities with different-sized sediments.<br><br>Investigate local areas of erosion. |
| 2. How is the Earth's surface being built up? | The Earth's surface may be built up to higher elevation where volcanoes create new rock material (lava, ash), and where forces inside the Earth cause the surface to push up, forming features such as mountains. | Use appropriate visual aids to learn about volcanoes and mountain building. |

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| ***3-6*** | | |
| 3. In what ways does the Earth's crust move? | Earth's crust moves horizontally and vertically (earthquakes, faults). | Use cardboard models of faults available from suppliers, or make your own models using clay. For more information and activities on earthquakes, use *Earthquakes: a Teacher's Package for K-6.*[1] |
| 4. How do we know that the continents have moved? | Continents that are far apart may have similar rocks and fossils, and can be shown to "fit" together. These observations provide some evidence that the continents have drifted apart. | Use a continental plate puzzle to show that continents can "fit" together. |
| C. How do rocks form? | | |
| 1. What happens to melted rock when it cools? | When liquid rock material called magma cools, it becomes igneous rock. Rock texture (mineral grain size) is determined by how quickly the rock material cools. Faster cooling promotes a finer texture. | Make several batches of fudge; vary the rate each batch cools, and note the change in texture. Examine several samples of fine-grained, coarse-grained, and glassy igneous rock. |
| 2. How can sediments become rock? | Sediments form layers. These layered sediments may be compacted and cemented together to form sedimentary rock. Some sedimentary rocks can form from minerals left as water evaporates. | Make a mixture containing a variety of sediments (clay, sand, small pebbles), and place in a tall transparent container, such as a large graduated cylinder or glass jar. Add water, shake the mixture thoroughly, and allow it to settle. Observe the results.<br><br>Do activities with a stream table. Dissolve salt, and observe how it forms a sediment by precipitation. |
| 3. How can rocks be changed? | Rocks may break into particles from which sedimentary rock may be formed. Rocks may be changed by heat and pressure (metamorphism) to form metamorphic rock. Rocks can be melted, resulting in magma, which cools to form igneous rock. | Use audiovisuals to illustrate rock transformations, which include igneous, sedimentary, and metamorphic processes. |
| 4. What materials that we use come from rocks? | Many classroom materials come from rock. Some common materials are steel, aluminum, glass, chalk, plaster, and marble. All classroom materials that do not grow come from mineral re- | Identify classroom materials that come from rocks; discuss refined/processed materials versus materials in their natural state. Discussion should include plastics from petroleum products as well as |

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| | sources. In most cases, energy used in the classroom comes from fuel resources. | metals from ores and non-metals, like building materials. Discuss local materials (from within the city, county, and state), U.S. materials, and imported materials. |
| D. What is soil and where does it come from? | | |
| ! How do rocks become soil? | Rocks become soil by weathering and erosion. As rocks break down, they change size (boulder, cobble, pebble, sand, clay). Decomposing organic matter (leaves, woody fragments) mixes with weathered rock and adds nutrients to the soil. | Examine soil with a magnifying glass. Grow plants in different types of soil. |
| 2. How deep is soil? | Soil varies in thickness. It can be very thick (measured in meters) or very thin (measured in centimeters). | Investigate soil depth and types in different areas. Describe differences. |
| 3. How does soil change with depth below the surface? | Top soil is a darker type soil on top of a different-colored layer of soil called the subsoil. Most plants grow in the top soil. If you dig below the subsoil, you will reach bedrock. The soil may have formed from this bedrock or may have been transported by water, ice, or wind. | Investigate soil composition and profiles from various places. |
| 4. How do we use soil? | We use soil to grow resources, like crops for humans and livestock and forests for wood and other products, and to landscape. | Locate primary growing areas of the U.S. and the world. Interview farmers or horticulturists about soil enhancement and protection. |
| E. What can we learn about geologic history by studying sedimentary rock? | The time required for rocks to be created and destroyed is usually long. When sediments are deposited in layers, the oldest layers are on the bottom, and the youngest layers are on the top. With compaction and cementation, the sediments become sedimentary rocks. Fossils are sometimes found in such rock. Fossils give clues about the environment in which the life forms lived, thereby contributing to an understanding of ancient climates and landforms. | Use audiovisuals to illustrate changes in the Earth over time. Use a stream table to show the formation of sedimentary layers. Observe models of simple geologic cross sections. Examine common fossil types, and contrast them with life forms today. See *Reflections in Time*[2] and *The Earth Has A History.*[3] |

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| F. Why do we need to be increasingly concerned about the Earth? | | |
| 1. How can we run out of a resource? | We can run out of a resource when all known occurrences of the material are in places where the material is impossible to obtain with current technologies; when known technologies are too costly to obtain it; or when the material is found in places that create a conflict of interest in land use.<br><br>Many resources, like oil and gas, are non-renewable. Other resources, like trees and plants, are renewable. All resources, including minerals, soils, and fresh water, must be used wisely. | Discuss news stories about resource shortages. |
| 2. What problems are caused by using resources? | Using resources unwisely may cause pollution and may destroy habitats. | Study ways that will minimize pollution and destruction of habitats (e.g., mining and manufacturing processes). Do activity to investigate acid rain. |
| ***6-9*** | | |
| A. How can we model the Earth's surface and its interior? | | |
| 1. How do we describe what we see around us? | To describe what we see around us, observations are essential. They must be made carefully and be recorded precisely. | Design descriptive activities using the classroom, the school, and the school grounds. Devise exercises for accurate placement of described objects (desks within room, bicycle rack on school ground). Use coordinates and scale. |
| 2. How do we know where we are on the Earth? | The location of observations must be accurately determined. | Use maps and globes to emphasize latitude-longitude coordinates, and topographic (contour) maps to illustrate concepts of elevation and relief. Use local aerial photographs. |
| 3. How do we know the Earth's size and shape? | Scientists use different types of indirect measurements to determine the Earth's size and shape. | Examine satellite photographs. For upper-level students, do Eratosthenes' experimental calculations in *Earth Science Investigations*[4] or in *Investigating the Earth.*[5] |

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| 4. How deep have we penetrated the Earth? | Drilling into the Earth has penetrated only a very thin outer layer measuring only slightly more than one-tenth of a percent of the distance to the Earth's center. | Use lectures, audiovisuals, discussions, and field trips to emphasize the limited direct access to the Earth's interior. Illustrate stratigraphy with jello layers of differing color and consistency. |
| 5. How can we learn about the Earth's interior? | Inferences about the remaining 99+ percent of the Earth's interior, which is not observable, can be made through studies of active volcanoes, magnetism, seismicity (earthquake waves), high temperature-pressure simulations, and meteorites. | Study concepts of seismic interpretations, sonar, and Earth magnetism. Construct models from data, and use audiovisuals to reinforce concepts. |
| B. How can we investigate rocks and minerals? | | |
| 1. What are rocks made of? | Rocks are made of one or more minerals (elements and compounds) and can be organized into a classification system based upon their constituents. About 8 to 10 common rocks occur over most of the Earth's surface. | Introduce mineral identification, emphasizing observation, physical properties, and crystal growth, not memorization. Compare minerals to rocks. Note the variation in minerals identified in different rocks. |
| 2. How do rocks form? | Rocks are formed by processes operating in various environments. These processes produce recognizable characteristics in rocks. According to the rock cycle concept, the basic rock types (igneous, sedimentary, metamorphic) can be transformed from one type to another. The rock cycle requires an understanding of magma, lava, crystallization, sediment formation, transportation and deposition, textures, cementation, precipitation, and deformation. | Make local observations of rocks, and build collections with maximum variety. Note similarities and differences. Present concepts and classification system; practice rock identification coordinated with audiovisuals and demonstrations of rock-forming processes. |
| C. How is the Earth's surface wearing down? | | |
| 1. How do rocks break down? | Rocks near the Earth's surface undergo changes from both physical weathering, such as abrasion and frost wedging, and chemical weathering, such as oxidation and solution. Climate and topography control which of these processes predominates. | Experiment with physical and chemical processes. For example, for freezing and thawing of water in confined and unconfined containers, measure expansion and contraction and effect on containers. Do activities with oxidation (rusting of iron) and solution of |

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| | | solids. Visit local cemeteries, or use photographs to observe differences in old and new monuments. |
| 2. What happens to weathered rock? | Weathering processes result in the alteration of rocks, which produce sediment and soils (residual and transported). | Observe some soil profiles, and note the changes in color, texture, and composition with depth. Examine local soils maps to show variations, and note the land use on the various soil types. |
| 3. How is weathered rock moved? | Weathering products are eroded and transported to other places by wind, water, and ice. Slopes are also reduced by processes of mass wasting. Slope stability is of primary concern in land use planning. | Explore principles of erosion and deposition using a stream table, sediment bottles, and field trips. Experiment with influence of water and gravity on slope stability. Measure angle of repose for sediments of different sizes and shapes. |
| 4. Where does weathered rock go? | Energy loss by transporting agents during movement of weathered rock results in deposition of particles. Physical depositional processes involve understanding the influences of gradients, currents, and waves. Flood plains, deltas, alluvial fans, loess, talus, and lake and ocean sediments are products of deposition. They exhibit depositional features that include sorting, graded bedding, and layering. | Use stream table to observe factors influencing erosion and deposition. Use a settling column to note relation of size to settling rate and to understand sorting, graded bedding, and layering. See *Erosion: Leveling the Land.*[6] |
| D. Why do we still have mountains? | | |
| 1. What makes mountains? | Mountains can result from volcanism, folding, faulting, earthquakes, and differential erosion. | Construct clay models, and use earthquake detection exercises and "slinky" models. In mountainous areas, observe hazards. See *Why Do We Still Have Mountains?*[7] |
| 2. Where are mountains found on the Earth? | Mountain chains are found on every continent, for example, along the entire west coast of the Americas, along the eastern border of North America, through the Mediterranean area, and in Asia. Long submarine mountains called ocean ridges, isolated volcanic mountains, and mountains along island arcs also exist. | Employing map exercises, identify and locate mountains of the U.S. and the world. |

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| 3. How can we explain the global pattern of mountains? | The theory of plate tectonics accounts for the types of mountains and their distribution globally. Important concepts involved in these theories include crustal collision, subduction, and rifting. These processes operate over a long period of time. Rates can be measured directly through using satellites or deduced over long intervals (millions of years) by applying geologic principles. | Using models and maps, discuss the significance of the patterns and types of mountains. Plot data on frequency and distribution of earthquakes and volcanoes. Illustrate concepts of crustal plates, their movement, and margins through video and movie animations. Demonstrate principle of convection cells. |
| E. How old is the Earth? | | |
| 1. What can we learn from layers of rock about the Earth's age? | Age relationships of rock layers can be determined by applying the laws of superposition, original horizontality, crosscutting relationships, and correlation. | Construct models and geologic profiles to reinforce principles of age relationships and correlation. |
| 2. What methods can we use to measure the Earth's age? | Radioactivity of some elements present in rocks make it possible to determine how many years ago the rock formed. Radiometric dating assumes a constant rate of decay, producing a predictable ratio of parent-to-daughter elements over a given period of time. The Earth is at least 4.5 billion years old. | Create geological time line, and use "shoe box decay" to illustrate radiometric dating technique. |
| F. How do we use Earth resources? | | |
| 1. What Earth resources do we need, and why do we need them? | To support and enhance life, we need such resources as metals, nonmetals, fuels, and precious stones. | Observe samples of ores and refined metals, fuels, coal and oil, and other economic minerals and rocks. Visit a museum, and utilize visiting scientists. |
| 2. Where do we find Earth resources that we need? | Earth resources are not uniformly distributed; therefore, some resources must be imported. | Make a list of important resources, and plot on appropriate map where they are known to be found. Include the occurrence of strategic materials. Include any Earth resources in your area that control the local economy. |
| 3. Why are Earth resources limited? | Earth resources are limited by existing known quantities, economics of acquisition, and competition for alternative uses of the land where they occur. | Highlight Earth resources using current events; hold debates on resource utilization, and invite visiting professionals to discuss resource issues. |

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| 4. What can I do to conserve Earth resources? | The limitations on resources require that plans for conservation, recycling, and multiple use be implemented worldwide. | Discuss values in recycling, visit a local recycling center, and note recycling issues in the media. |
| ***9-12*** | | |
| A. How do we use the lithosphere?<br>1. How and where do we get energy from the solid Earth? | Energy from the solid Earth is derived from the upper layers of the lithosphere (crust) through drilling and mining. Sources of energy from the crust include fossil fuels (coal, oil, natural gas) nuclear fuels, and geothermal sites. | Determine the local sources of energy for heating homes and manufacturing. Visit a power plant. Research the types and sources of energy derived from the crust, which are utilized in the state, nation, and world. Conduct a study of geothermal energy locales. One source of information is the California Department of Conservation.[8] Construct models of oil traps. Determine relative supplies of various crustal energy sources. Conduct discussions and debates on the pros and cons of alternative energy use (wind, water, wood, and waste). |
| 2. What solid Earth materials do we use, and where do we find them? | Most of the materials with commercial value found at or near the Earth's surface (soil, rock, minerals, fuels) are used. | Study samples of metallic and nonmetallic minerals. Perform an extraction lab with calculation to determine quantity from ore minerals (e.g., copper). Determine sources of important minerals and their uses. Plot locations of resources on maps. Display map of private, Indian, state, and federal lands in the U.S., and compare with sites of coal, oil, gas, and mineral production. |
| 3. How does the lithosphere influence agricultural production? | Materials of the lithosphere are the source for all soils. | Examine local excavations, and note soil characteristics and underlying rock. Compare soils maps with geologic maps. Determine areas of high agricultural productivity, and note soil and rock type. Determine soil characteristics related to topography and climate. |

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| 4. What are the advantages and disadvantages of using the Earth's resources? | Earth resources are essential to sustain and improve the quality of human life, yet their use may create severe problems of resource depletion, pollution, and undesirable surface alteration. | Determine resources that are renewable and non-renewable. Choose several resources and develop a list of beneficial versus detrimental effects of their uses. Compare rate of use with known reserves of several commodities. Determine which of these resources are amenable to recycling. Form a panel: developer, environmentalist, politician, citizen. Debate (requires library research and writing) issues of stewardship, conservation, pollution, and surface damage. Develop a recycling system at school. Visit a local center. |
| 5. How does law influence use of the land? | Legislation is essential to maximize the wise use of the Earth's surface and its natural resources. | Invite a guest speaker to discuss rights of property owners regarding minerals underlying their property. Research local or state ordinances controlling land use, building codes, and reclamation of mined areas. |
| B. What is the solid Earth? | | |
| 1. How do we measure the Earth's dimensions? | The Earth's dimensions may be determined by using indirect or direct measurements. Eratosthenes, a Greek geographer, used indirect methods to measure the Earth, while today we can directly measure the Earth with artificial satellites. | Do Eratosthenes' experiment in *Earth Science Investigations*[9] or in *Investigating the Earth.*[10] Calculate the Earth's size using a simple road map showing latitude and a ruler. Track satellite launching from U.S. Navy communications. Discuss latitude-longitude, polar-equator diameter ratios. |
| 2. How can we determine the Earth's composition and structure? | The Earth's composition and structure are known from detailed studies of surface materials, studies of volcanoes, drill hole samples, and inferences made from geophysical data. | Observe and interpret geolo[illegible] maps, Landsat images, and stereo photographs. Examine rock cores from drilling in local area (sources: local highway department, well-driller, state geological survey). Invite geoscientist to discuss local and regional geology. Study principles of geophysics, and illustrate correlation of data with properties of Earth material. Observe a seismogram, and use S-P wave time-travel graph to locate an epicenter. Conduct seismic wave demonstration with "slinky" and rope. Use au- |

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| | | diovisuals to assist in presenting concepts. See current computer software catalogs for appropriate activities. |
| C. What clues do rocks and minerals give us about how they were formed?<br>1. How do rocks and minerals form? | Physical and chemical laws control the formation and characteristics of minerals and rocks. | Discuss ways that minerals may form through igneous, sedimentary, and metamorphic processes. Design laboratory studies of minerals, crystals, and rocks, which emphasize physical and chemical characteristics of minerals and rocks. Use field trips to observe local mineral and rock occurrences, and geologic maps to show national and worldwide rock distributions. Introduce concepts of classification related to chemical relationships and physical properties. |
| 2. How do rocks undergo change? | All rocks may undergo changes by long-term exposure to different environments. The rock cycle concept represents these changes. | Develop a list of ways rocks may be changed, and identify the conditions favorable to those changes. Display local samples that may represent various environments of origin, and compare with rocks from other regions of the world. |
| D. How do rocks help us determine the Earth's age?<br>1. How can we use the relative dating method to determine sequences of geologic events? | Relative ages of rocks and events in the Earth's history can be determined by applying the laws of uniformitarianism, original horizontality, superposition, cross-cutting relationships, and inclusions. | Use audiovisuals in introducing the concepts of geologic time and history, for example, slides and films depicting episodes by rock relationships. Solve relative age problems from pictorial clues. Examine and interpret geological cross sections exhibiting folding, faulting, intrusions, and erosion. Experiment with developing three-dimensional models to emphasize relationships. Take field trips to local exposures of rock outcrops or quarries. |

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| 2. How can we use numerical dating techniques to determine rates of geologic change? | The age of the Earth and individual events in its history can be determined by various radiometric dating techniques. Dendrochronology and studies of varves are other useful dating techniques. | Study principles of radioactivity and applications to dating geologic materials. Laboratory activities should reinforce discussions by illustrating concepts of decay and half-life. Measure some rates of change, and derive a time frame (e.g., the Grand Canyon); observe tree sections. |
| E. How is the Earth's crust moving? | | |
| 1. What is the theory of plate tectonics? | The rejected theory of Alfred Wegener, known as continental drift, postulated that a supercontinent, Pangea, broke into pieces, forming the present continents, which drifted to their present positions. Today, modified by redefinition of the "pieces" and the mechanism for "drifting," the concept is referred to as plate tectonics. The pieces are called plates, which may be oceanic or continental crust or both. They move by sea-floor spreading. | Use a globe or map to see how the continental boundaries seem to "fit" together. |
| a. How do we know that lithospheric plates move? | Evidence of plate movement includes continental fit, age of the sea floor, studies of earthquake foci, and paleomagnetism and magnetic reversals, plus direct measurement using satellites. The rate of plate movement is measured in centimeters per year. | Use large globes in raised relief. Use activities similar to those in the Crustal Evolution Education Project (CEEP) modules.[11] The evidence supporting the theory of plate tectonics should be studied and supplemented by graphics and animation of processes in films and videos. Use geophysical investigations such as those in the *Laboratory Manual in Physical Geology*.[12] |
| b. How do crustal and mantle processes relate to plate tectonics? | Unequal heat distribution beneath the crust and in the mantle is believed to be the primary cause of plate movement. These movements can cause rifting and sea-floor spreading, collision, and subduction of plates. Local hot spots have also been detected. | Use maps showing sea-floor spreading and continental margins, and make fault models using materials such as wood or clay. Illustrate hot spot theory with Hawaiian Islands and Yellowstone National Park. |

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| c. How do crustal features relate to plate tectonics? | Most of the Earth's oceanic and continental features are the result of the movement of lithospheric plates. | Study the distribution of global features: midocean ridges, marine trenches, island arcs, mountains, submarine volcanoes, guyots, grabens, and rifts. Use laboratory activities to learn characteristics of plate margins and their locations. Display these features using computer software, models, and other visuals. |
| 2. How does the Earth's crust adjust to changes in load? | The Earth's crust responds to loading by downwarping (sinking) and to removal of load by rebounding (rising), achieving isostatic equilibrium. | Study principle of isostasy and demonstrate using various sizes of Ivory soap or wood blocks in cold water or ice in jello. Study aerial photographs of abandoned shorelines, especially of Great Lakes to show rebound from glacial melting. Discuss Darwin's theory of atolls and seamounts. Devise laboratory activity on loading the sea floor. |
| F. How do we recognize landforms produced by constructional processes? | High elevations, such as volcanic mountains and linear mountain ranges, are considered landforms that result from constructional processes. | Compare landforms, such as mountains, using models and topographic maps. Use slides and videos extensively. Take a field trip to a volcano, if possible. |
| G. How do we recognize landforms produced by degradational processes? | Some landforms are caused by processes that reduce the land surface (weathering and erosion) causing differences in elevation. Other features are created by moving the eroded materials to lower elevations (deposition) by water, wind, and ice. | Use stream table activities to simulate features that result from stream flow and waves, and observe mass movements. Take local field trip, and observe work of streams and associated mass wasting. Visit a local construction site to see sedimentary features. |
| H. How do we depict the Earth's surface and subsurface?<br>1. How do we use maps to study the Earth's surface and subsurface? | Maps of the Earth's surface and subsurface are used to convey the accurate position of various features. Maps depict variations in elevations and the distribution of Earth materials, such as soil, rock formations, water, and fossil fuels. | Review use of planimetric maps to show routes (highways) and locations of features. Conduct laboratory activities involving grid systems. Learn to use Brunton compass to make a map of the schoolyard. Make a topographic map from federal and state topographic, geologic, and soil survey maps. Make a three-dimensional model of topographic map. |

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| ***9-12*** | | |
| 2. In addition to maps, what other tools and technologies are used to study the Earth's surface and subsurface? | Aerial photographs, satellite photographs, computer-enhanced images, side-scanning radar, and computer modeling are among the many tools and technologies used to study the land. | Examine the details of a local area on an aerial photograph. Demonstrate advantages of stereo pairs. Study images and the uses of satellite imagery and computer modeling. Construct three-dimensional geologic models. |
| I. Why are some areas of the Earth's surface considered hazardous for use? | Active geologic processes at the Earth's surface may present risks in using many land areas. | Study historical records for results of landslides, volcanic eruptions, earthquakes, collapse of sinkholes, coastal storms, and similar events. Use visuals to demonstrate severity of natural hazards, and explore methods to predict them. Learn, through library work and discussions, methods that may limit or control hazards. Identify potential problems on maps, and demonstrate the use of "risk" maps published by the U.S. Geological Survey and state planning agencies. Discuss the reasons for land use regulations. |
| J. What careers are available in the study of the solid Earth, and what other types of employment require knowledge of this discipline? | Careers in the geosciences, such as geology, geophysics, geochemistry, petroleum geology, economic geology, engineering geology, environmental geology, seismology, mineralogy, petrology, structural geology, and volcanology, are keys to finding new sources of useful Earth materials and to understanding Earth processes that affect our lives. Examples of other professions that require knowledge of the Earth are civil engineering, construction, farming, architecture, real estate, and land use planning. | Lead discussions, and develop a list of professions whose work deals with some aspect of Earth characteristics. Invite speakers, and hold panel discussions by local professionals representing the professions identified. Plan a project to emphasize careers in science and technology. |

# *Water*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| A. What are the different forms of water? | | |
| 1. What are some properties of liquid water? | Pure liquid water is clear. Water reacts differently to various materials and surfaces. | Using your senses and a magnifying glass, observe and describe what a drop of water does when placed on different surfaces (e.g., wax paper, paper towel, desk, finger tip). |
| | Water takes the shape of its container. | Pour equal amounts of colored water into different jars. Compare and contrast different sizes and shapes. |
| | Some things dissolve in water. | Describe what happens when sugar is added to water. |
| | Certain objects float in water, while others do not. | Study what happens when you place things in water. Classify those that float or sink in water. |
| 2. What are some properties of solid water? | Ice, snow, frost, and hail are forms of water that have changed to a solid. Ice forms when liquid water is cooled to freezing. When ice warms, it changes to liquid water. | Give students a clump of snow or an ice cube. Observe, measure, and describe changes over a period of about five minutes. Have them draw what they see, comparing and contrasting shape and size. |
| | Water in its solid state is brittle. | Observe what happens when an ice cube is struck with a hard object like a hammer. **Caution:** *Cover ice cube with towel to protect students from flying pieces.*<br><br>Read *Snowy Day.*[1] |
| 3. What are some properties of water vapor? | When liquid water is heated, it turns into an invisible gas called water vapor. When water vapor is cooled, it can become liquid water. | As a demonstration, show students what happens to liquid water when it is heated. Place an immersible heater in a container of water. **Caution:** *Students should not touch the heater or the hot water.* Describe what you see. Hold a cool surface (e.g., metal mirror) over the heated water. Describe what you see (condensation). |

| *Water*<br>*Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| | | Go outside on a cool day, and observe your breath. |
| 4. What is a cloud? | Clouds are made of different forms of water. The oceans are a major source of the water from which clouds form. | Brainstorm "What is a cloud made of?" Write a poem describing clouds. |
| | Clouds occur in a variety of shapes. | Over several days, observe clouds change. |
| | Some clouds bring rain or snow. | Compare different types of clouds with different types of weather. |
| | | Using cotton, create models of different clouds. |
| | | Complete the sentence, "My favorite cloud shape is _____." |
| 5. Where do we find water? | Water can be found in many places as a liquid, solid, or gas. | Discuss where water is found in the school, in the home, and outside. Draw pictures to illustrate where you find water, or cut pictures from magazines and make a collage. |
| | Water can be found underground as well as in rivers, lakes, and oceans. | To study where rainwater goes, make observations and construct collages or drawings. |
| B. How can we use water? | Water is necessary for all living things. Water has a variety of uses, such as drinking, cleaning, and recreation. | Do a survey to show how water is used in the school, for example, in places such as the drinking fountain, cafeteria, and restrooms. |
| | | Survey family and extended family, and report on how the family uses water. |
| | | Classify essential uses of water (e.g., fire safety, cleaning, cooking, bathing, watering plants, caring for pets). |
| C. What is the difference between clean and dirty water? | | |
| 1. What is dirty water? | Dirty water is water that has undesirable materials in it. | Study how we can make dirty water. Mix one teaspoon of potting soil with one quart of water. Ob- |

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| | | serve and describe. Mix one teaspoon of sand with one quart of water. Observe and describe. **Caution:** *Do not taste.* |
| | | Do an activity to describe dirty water. Bring in samples of dirty water, such as water found in ponds and puddles. Use a magnifying glass to observe and describe them. |
| | Dirty water may look clean but be unsafe for our use. | Do this demonstration or group activity to discuss how we can tell if water is safe to drink. Using clean water and three clear containers, add one teaspoon of sugar to one container, one teaspoon of salt to another container, and nothing to the last container. Taste the water in each container, and compare and contrast. **Caution:** *Students should not drink from the same container.* For example, have all students describe the clean-looking water in all three containers. But have only one student sip from the containers to describe to the other students the taste. What can we say about clean water? |
| | Water can be used again if it is treated properly. | Study what soap does to water. Have one or more students wash their hands with Ivory soap, and describe the water afterwards. Can this soapy water be used again? Observe, compare, and contrast with clean water. What should be done before we use this water again? |
| 2. What can cause water pollution? | People and nature add many materials to water, which pollutes it. | Discuss where we can find dirty or polluted water. Include in the discussion the concept that some places are naturally polluted. Bring in pictures of polluted and non-polluted streams and lakes, and compare and contrast. |
| 3. How can we conserve water? | Clean water is a finite resource. We should use water wisely by not wasting it. | List ways we waste water. List ways we can save water. |

| *Water*<br>*Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| *3-6* | | |
| A. Why is water special? | | |
| 1. What properties make water special? | Water is a good solvent. Due to its surface tension, it can draw up into small spaces, for example, between soil particles and rock fractures. Water expands when it freezes. It remains a liquid over a large temperature range, between 0°C to 100°C. | Conduct activities to investigate the solvent properties of water and capillary action. Do activities to investigate freezing water. |
| 2. Why is water necessary in our lives? | Water is necessary to sustain and enhance life. Its uses include irrigation, bathing, drinking, recreation, transportation, household use, waste disposal, and industrial processing. | Identify local sources of water. Investigate how water is used in your area. |
| B. Where is water found? | | |
| 1. Where is water found in the air? | Water is found in the air as water vapor, fog, condensation, and clouds. | Do activities demonstrating condensation and formation of steam. |
| 2. Where is water found on the surface of the Earth? | Water is found on the surface of the Earth in rivers, streams, lakes, ponds, oceans, and glaciers. | Use maps of local area to identify surface water. Make neighborhood observations. Use maps of state, U.S., and world to locate water bodies. Compare amounts of fresh water with amounts of salt water. |
| 3. What clues do we have that water is in the ground? | Caves, wells, and springs give us clues that water exists underground. Since plants use water from the soil, they may also give us clues to the location of water in the ground. | Experiment with plants: investigate the relationship between roots and water. Do roots grow towards a source of water? Observe the distribution of plants in your local area. |
| C. How does water move from place to place? | Water flows downhill. Water evaporates into the air. Water is in many Earth materials and living things. Water is transformed cyclically from solid to liquid to vapor. | Experiment with evaporation, condensation, and precipitation. Design an experiment to learn if water is involved in making popcorn pop. |
| | Ocean water is continuously moved by currents and tides. | Study map of ocean currents. Study tide charts. |

## *Water*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***3-6*** | | |
| D. How does water cause changes on the Earth? | | |
| 1. How does moving water change the Earth's surface? | Moving water changes the Earth's surface by wearing it down (erosion) and building it up (deposition). Moving water carrying suspended materials can make rocks smooth by abrading them. | Make local observations of erosion and deposition. Construction sites and stream valleys show obvious examples. Observe various stages of water-worn rocks from different sites. Use a rock tumbler to make rocks and minerals smooth. |
| 2. What difference does the amount of water make in an environment? | The amount of water available in an environment causes the environment to have different animals, plants, weather, climate, and human lifestyles. | Locate and compare environments and habitats in terms of the type of animals, plants, weather, climate, and human lifestyles. |
| E. Why do we need to be increasingly concerned about Earth's water resources? | | |
| 1. Where does drinking water come from? | Fresh drinking water is obtained from rivers, lakes, and ground water. Water can be stored in reservoirs. Water can be purified. Salt can be removed from sea water by distillation. | Design a flow diagram showing how water travels from its source to the school faucets. Take a field trip to a local water treatment plant. Study how to distill sea water. |
| 2. Where does waste water go? | Waste water goes down a drain and may flow to a septic tank or to a treatment plant. During treatment, some water may evaporate. Since waste water is not destroyed, it will eventually flow into the ground and downhill to the ocean. | Construct a flow diagram of waste water disposal and treatment. Do activities to learn water recycling on a spaceship. |
| 3. How do our activities affect water? | We affect the Earth's water quality by creating public and industrial waste water. Agriculture affects water quality through using fertilizers and pesticides. Power generation plants use water for cooling, which makes the water warmer. We affect water quantity by depleting aquifers without recharging them. Rock formations that yield significant quantities of water are known as aquifers. | Read newspaper and magazine articles about aquifer depletion. Study local problems related to water quality. |

## *Water*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***3-6*** | | |
| 4. What can be done to provide cleaner water in the future? | As the world's population increases, more people will need clean water. Wise use will help provide enough clean water. | Identify local water needs. Begin a "wise-use" activity program for water. Study where other countries have water quality and quantity problems. |
| 5. Who owns Earth's water? | Laws are written to decide who owns water. These laws can make a difference in the ways water can be obtained and used. | Study water use laws in your area. |
| ***6-9*** | | |
| A. How do the waters of the Earth circulate? | | |
| 1. Where do we find water? | Water is found in ocean basins, ice caps, lakes, rivers, the atmosphere, and underground. | Examine local area to note occurrences of water. Use maps to supplement personal investigation. |
| 2. How does water enter the atmosphere? | Water enters the atmosphere by evaporation, transpiration, and volcanic emissions. | Demonstrate or experiment with liquid-vapor transformation and rates. |
| 3. How does water come out of the atmosphere? | Water is removed from the atmosphere by processes that cause precipitation in the form of rain or snow. | Use a cloud chamber to illustrate condensation of water vapor. Demonstrate conditions for condensation and frost, incorporating concept of dew point. |
| 4. How does water flow over the land? | Water falling to the Earth flows over the surface as runoff, in sheets, and through intricate systems of channels to lakes and oceans. | Use a stream table to illustrate effects of precipitation on runoff and flooding. Gather data about precipitation and flooding for the local area, and note any influence on land use. Obtain land use maps from local government agencies. |
| 5. How does water move through the ground? | Much of the water falling to the Earth infiltrates through interconnected openings between particles (pores) along fracture planes and solution cavities. Movement of water through these openings is in response to gravity and resultant pressures in zones of confinement. | Using models, experiment with porosity, permeability, and capillarity to convey concepts of aquifers, water tables, and artesian systems. To do a permeability and porosity activity, see *Investigating the Earth.*[2] |
| B. How can we investigate the oceans? | | |
| 1. Why are oceans salty? | The salinity of the oceans results primarily from the long-term | Experiment with the influence of evaporation on salt concentration. |

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***6-9*** | | |
| | supply of dissolved minerals by volcanic activity (surface and subsurface) and by rivers (weathering and erosion). | Use audiovisuals of underwater volcanic activity. |
| 2. How do ocean waters change with depth? | Great variations exist in the nature of marine environments, from the illuminated upper waters, to the darker, colder, higher pressure waters on the bottom. Ships and various kinds of submersibles are used to explore ocean depths. | Demonstrate or experiment with density stratification in water. |
| 3. What makes ocean waters move? | Surface waters of the oceans are set in motion largely by wind-generated waves, the Earth's rotation, and sometimes by earthquakes and volcanic eruptions. Deep-ocean circulation is caused by gravity and density. | Use maps to study ocean currents; wave tanks (large aquaria) to demonstrate wave action; and audiovisuals to understand concepts of deep-ocean circulation currents. |
| 4. How does water motion in the oceans affect us? | Circulation within the oceans greatly influences global climatic patterns and causes erosion and deposition along coastal areas. | Use maps, audiovisuals, and articles on current events to investigate the influence of ocean dynamics on coastal areas, commerce, and climate. |
| C. How can we use water more wisely? | | |
| 1. How do we use water? | Water is not only an essential commodity to sustain life, but it is used in agriculture, power generation, manufacturing, mining, recreation, and transportation. | Make observations about local water uses, and tabulate. Visit manufacturing plants, recreational areas, and docks or ports. |
| 2. Where does the water we use come from? | Water is distributed to users from a variety of sources that include rivers, lakes, and reservoirs on the surface and wells underground. | Visit local water plants, and observe sources used. |
| 3. How does water change when we use it? | Water characteristics may change during water usage. Water may become laden with bacteria, chemicals, and sediment or undergo temperature changes. | Visit sewage treatment, food processing, or other industrial plants to learn about changes to water through its use. Test water samples above and below manufacturing plants along streams. |
| 4. What can we do about harmful changes to water quality? | Harmful changes to water quality are correctable but usually at great expense. Practical ways to minimize pollution should be employed. | Use audiovisuals and articles on current events to emphasize importance of maintaining high water quality. |

## *Water*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| A. What is the water cycle? | | |
| 1. How does water change in the water cycle? | In the water cycle, water undergoes constant changes in location, phase, and energy level. | Refer to standard laboratory exercises in chemistry and physics, which can illustrate the energy exchanges required to produce evaporation, condensation, and precipitation. Use audiovisuals to illustrate energy relationships along a stream (runoff) and the influence of gravity in promoting infiltration and pressure variations in Earth materials. |
| 2. How is new water introduced into the water cycle? | New water is introduced into the atmosphere and hydrosphere by volcanic activity. | Obtain data on water content of rocks and volcanic eruptions. |
| B. Why are the oceans important? | | |
| 1. How do oceans affect weather and climate? | Ocean currents, which transfer large volumes of warm and cold waters, profoundly affect world climatic patterns. | Study the influence of the Coriolis effect on horizontally moving ocean currents (e.g., Gulf Stream, Kuroshio Current). Use visuals to illustrate horizontal deflections, upwellings, and downwellings. Use laboratory experiments to illustrate currents generated by wind and density differences. Plot major currents of the world on maps and globes. Illustrate with the El Niño Current the effect of ocean currents on climate. |
| 2. How do oceans affect the land? | Large bodies of water, such as oceans, produce a moderating effect upon climate and are responsible for erosion and deposition by waves in coastal areas. | Conduct laboratory activity to demonstrate uneven heating of land versus water. See *What Makes the Wind Blow?*[3] Collect and graphically represent climatic data on inland versus coastal areas of the same latitude. Determine the influence of the Great Lakes. Use field trips or visuals or both to observe effects of erosion and deposition. Use wave tank to demonstrate effects of waves on shores. |
| 3. How do oceans affect the composition of the atmosphere? | Gaseous exchanges between ocean waters and their organisms and the atmosphere result in variations in atmospheric composition. | Study mechanisms of gaseous transfers (interactions) between oceans and the atmosphere, for example, solution, evaporation, condensation, photosynthesis. |

## *Water*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| 4. What resources were formed by ancient oceans? | Many mineral, petroleum, and gas resources were formed in ancient oceans. | Review origins of sedimentary rocks, and tabulate rocks that indicate a marine environment. Establish current usage of rocks listed. Discuss distribution of ancient oceans and seas. Study theories of oil and gas formation. |
| 5. What resources do present-day oceans provide? | Both renewable and non-renewable resources come from present-day oceans. These resources include minerals, energy, food, and drinking water. | Through library work and reports, learn the scope of ocean resources. |
| 6. How does human activity affect oceans? | Human activity affects the composition of ocean waters and sediments, thereby the ocean flora and fauna. | Study effects of pollution on the resources identified. Hold debates and invite politicians and industrialists to discuss issues. Compose awareness letters for the media. |
| C. What are the characteristics of subsurface water? | | |
| 1. How is subsurface water stored? | Huge amounts of water are stored underground in the openings between mineral and rock fragments. | Conduct an experiment to determine the porosity of different-sized particles, such as sand, gravel, marbles, BBs, and the effect of mixing various-sized particles (varying the degree of sorting). Use colored water to establish a saturated zone and water table in a stream table or wave tank. Supplement finding with diagrams and videos. |
| 2. What controls the movement and rate of movement of subsurface water? | Movement of subsurface water is controlled by the pressure gradient and the physical and structural properties of the materials through which the water moves. | Demonstrate or experiment with the relationships between particle size, sorting, porosity, permeability, capillarity, and surface tension. |
| 3. How can subsurface water reach the surface? | Water from underground saturated zones commonly reaches the surface naturally by gravity seepage and gravity-induced pressure; less frequently by local high temperatures at depth (e.g., Yellowstone geysers); and by pumping from wells. | Construct a model to illustrate a water table, an aquifer, and an artesian system. Using the model, a hose, or glass tubing, demonstrate artesian pressure, and calculate hydraulic gradient. Supplement activities with graphics and videos to clarify occurrences of springs, wells, and geysers. |

| *Water*<br>*Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| *9-12* | | |
| 4. What controls the quality, quantity, and availability of subsurface water? | The abundance of underground water is directly related to climatic factors; its quality and availability are dependent upon the Earth materials through which it moves and the possible influence of surface activities. | Discuss concepts within the water cycle, and investigate the relationships between precipitation and evapotranspiration. Research ground-water conditions in semiarid versus humid climates. What percent of precipitation results in runoff versus infiltration in each area? Test the hardness of local water supplies, and discuss the reasons for hardness and softness. Test water for pollutants. Discuss results. |
| 5. How does subsurface water influence human activity? | Particularly in arid and semiarid regions, the development of population centers depends upon reliable sources of subsurface water. | Invite hydrogeologist to speak on local and regional ground-water supplies and uses. Develop a list of uses; have students or teams of students determine agricultural and urban water usage and how usage affects the water table. Plot data on maps and discuss. Investigate the relationship between crop distribution and water supply. |
| 6. How does human activity affect subsurface water? | Human activities, such as agriculture, manufacturing, mining, and development of population centers, demand enormous amounts of water and can produce deleterious effects upon a subsurface water source that supports them. | Lead discussion on how subsurface water may be changed by pollution sources, construction, paving, and overuse. Investigate water budgets. |
| D. How is surface water distributed? | | |
| 1. How does precipitation influence the occurrence of surface waters? | Sufficient precipitation results in waters flowing on the surface in rills and valleys as runoff, as well as in static accumulations in basins and areas with limited slope. | Study U.S. Geological Survey topographic maps, and categorize the surface water accumulations noted. Take field trip to observe surface waters in the local area. |
| 2. How do streams and lakes change through time? | All bodies of surface water undergo change within a comparatively short span of geologic time. Streams change in position, gradient, and discharge. Lakes fill with sediment and may become eutrophic. | Use stream table activities to observe processes of erosion and deposition. Use visuals employing animation to emphasize how streams and standing bodies of water change over time. Use maps to study stream characteristics, for example, meanders and longitudi- |

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| | | nal and cross-sectional profiles. Use field trip to enhance understanding. |
| 3. How are surface and subsurface water related? | Subsurface water and surface water form a continuum, each supplying water to the other. | Use visuals, slides, and videos to show relationships between ground water and surface water. Make three-dimensional models in plexiglass; draw and interpret two-dimensional diagrams. Study topographic maps to illustrate spring-fed lakes and streams, disappearing streams, and influent and effluent conditions. |
| 4. What are the effects of moving surface water? | | |
| a. How does moving surface water modify the landscape? | The kinetic energy of flowing surface water causes the water to erode the landscape over which it flows. When the level of kinetic energy of a stream diminishes, the stream may deposit sediment on the landscape. | Discuss the reasons for variations in the kinetic energy of flowing water. Using a stream table, experiment with effects of changes in slope and water volume. Study maps to analyze where erosion and deposition are taking place along stream valleys. |
| b. How can moving surface water be used to produce energy? | The kinetic energy of naturally flowing surface water can be converted to power through the use of water wheels and turbines. | Conduct a laboratory experiment on hydroelectric production of energy. Research locations of hydroelectric plants. Determine if there are current or historical local uses of flowing water. |
| 5. How does surface water influence human activity? | Surface water bodies provide opportunities for development of population centers and industrial and recreational uses. In earlier times, rivers and lakes provided major transportation routes. | Discuss reasons why industrial and residential development are closely associated with surface water. List the local uses of water, and plot on a map. Is there a pattern to the industrial, residential, and recreational areas? Invite local planner to speak to class. |
| 6. How does human activity affect surface water? | Using surface water can cause the water to change chemically and physically. | Use data on water uses to explore ways a use may change water's quality. For example, research how municipalities, residences, recreation, and industry can change water's quality. |

## *Water*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| E. How do laws affect our use of water? | Because water is vital to society, laws are enacted to minimize deleterious changes in water's quality, quantity, and availability. | Emphasize local controls over water use. Invite outside speakers, and hold debates. Research differences in eastern versus western regulations. States like Texas and New Mexico have different regulations concerning water use. Evidence of this difference can be observed on Landsat images. |
| F. What hazards are associated with water, and how can we mitigate them? | Though water is an essential commodity, its presence can become hazardous in uncontrolled quantities and quality. | Discuss how geological events, such as erosion, flooding, rock weathering, sinkholes, and subsidence, can result in local hazards. Do flood prediction activity. |
| G. What kinds of technology are used to study the hydrosphere? | The importance of water to civilization has stimulated the application of diverse technologies to understand the global relationships within the hydrosphere. These technologies include satellite imagery, aerial photography, manned and unmanned submersibles, and sonar. | Enumerate and discuss some technologies used to study the hydrosphere. Include use of satellites to obtain data from remote sites, and use of modern instruments to measure soil moisture, water quality, and water quantity. |
| H. What careers are available in the study of the hydrosphere, and what other types of employment require knowledge of this discipline? | Hydrologists, hydrogeologists, limnologists, and oceanographers provide basic information to society about water or Earth. Examples of others who need an understanding of the physical and chemical characteristics of water and its natural occurrences are farmers, land developers, environmental geologists, marine biologists, mine operators, waste disposal and treatment operators, politicians, and city engineers. | Conduct research on use of water by professions, and invite guest speakers from among those professions. |

# Air

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| A. How does weather change?<br>1. What is today's weather? | Weather describes what the air is like outside at a particular time and place. | Look at today's weather, and describe it, for example, sunny, not sunny, cold, warm, rainy, not rainy, windy, not windy.<br><br>Draw a picture of today's weather. Later in the day, draw another picture, especially if the weather has changed. Compare the weather conditions depicted in the two pictures to see if anything changed. |
| 2. How does weather change from day to day? | Changes in temperature, water content (humidity), precipitation, clouds, and wind can occur over short periods of time, like hours and days.<br><br>Weather observations can help us predict weather. | Bring in weather forecasts from newspapers, or write down forecasts from TV or radio. Compare these forecasts with what actually happened.<br><br>Look at weather maps to find out where you live. Teacher makes a weather chart for the whole class. Students make their own charts. A minimum of five days and possibly several weeks would be best, with observations made during the time of year when weather changes the most. Weather symbols can be used. Count such things as the number of sunny days, windy days, and rainy days. Use simple graphs to summarize data. Compare class chart with student charts. |
| 3. How does weather change from season to season? | Weather also changes over long periods of time, like months and seasons. | Integrate art, music, and poetry to illustrate seasonal changes. Draw a picture of your favorite season. Compare and categorize the drawings. Be sure that all four seasons are considered.<br><br>Draw pictures or make collages of school yard or park for each season. Consider the following questions: What is the typical weather for this season? How do plants and animals respond to this season? What do we do during this season? How do we dress for this season? |

## *Air*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| | | What kinds of activities are associated with this season? |
| B. How does weather affect us? | | |
| 1. How does weather affect our activities? | The weather determines if we will do indoor or outdoor activities. | Discuss what kinds of things you will do today. How does the weather affect your choices? Draw or make collages of favorite things to do on days with different weather. What would your family do if they planned a picnic and the weather changed?<br><br>Refer to last week's weather chart to see how the weather determined what you did. |
| 2. How should we dress for different weather? | The weather determines what type of clothes we decide to wear. | Discuss what type of clothing is best for today's weather. Discuss what type of clothing you would wear for a hot, sunny day versus a cold, wet day. For example, how do clothing color, weight, and thickness differ for the two days? Make a collage of pictures of clothing you would wear for different weather conditions. |
| 3. How does weather affect the way we design our homes? | The weather determines how we build and furnish our homes. | Bring in pictures of how homes are built in warm versus cold parts of the country. Discuss the differences. Discuss how we change our homes to accommodate seasonal changes in weather. |
| 4. How do we protect ourselves from weather? | Weather can be dangerous. We need to protect ourselves from too much heat, cold, wind, snow, rain, or lightning. | List types of dangerous weather, such as lightning, tornadoes, blizzards, hurricanes, hail, severe cold, very hot weather, fog, and air pollution.<br><br>Prepare a weather safety booklet for your home and neighborhood. Contact the local Federal Emergency Management Agency office for information. |

# *Air*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| C. What is air pollution? | | |
| 1. What is in air to make it dirty? | Dirty air is air that contains materials that are harmful to living things.<br><br>Dirty air may look clean. | Brainstorm and discuss questions such as the following: What things are in dirty air? What places have really dirty air? Can we always see dirty air? How do we know the air is dirty? How can a blind person tell there is smoke in the air? Without the students seeing it, open a bottle of perfume or anything with a strong odor. Ask the students to describe the air in the classroom. Can you always see air pollution?<br><br>Cover squares of stiff cardboard with vaseline, and hang outside in different areas. Make observations over a period of time, and classify what you see. Locate newspaper and magazine pictures of dirty air, or make drawings.<br><br>Write about such ideas as "If you were a bird, where would you like to live?" Give reasons. |
| 2. What causes air pollution? | Humans and natural processes change the air, sometimes causing air pollution. | Consider what things put smoke and other pollution into the air. Cut pictures from magazines, and make lists.<br><br>Discuss what we can do to keep the air clean. |
| ***3-6*** | | |
| A. What is special about the air? | | |
| 1. What do our senses tell us about the air? | Our senses allow us to feel changes in weather. Our senses detect things that air carries from place to place. | Use your senses to observe weather variables, such as temperature, humidity, cloud cover, and wind speed and direction. Use your senses to detect pollen, smoke, and sound. Discuss how you can extend your senses to make and record observations. |

## *Air*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***3-6*** | | |
| 2. What is air made of? | Air is a mixture of gases made up primarily of nitrogen and oxygen. | Place a Pyrex beaker over a small candle, and observe what happens to the flame. Discuss why the flame extinguishes. |
| 3. What needs air? | Air is essential for life. Animals need oxygen, and plants need carbon dioxide. Burning requires oxygen. Engines use oxygen. Air is needed for flight. | Study how the lack of an atmosphere on the Moon causes the Moon to be different from the Earth. List uses of air. Experiment with paper or balsa wood airplanes to show how air enables flight. |
| B. How does weather change? | | |
| 1. How do we know when weather changes? | We can use our senses and instruments to tell when weather conditions change. Changing weather conditions include amount and type of precipitation, wind speed and direction, cloud cover, temperature, and humidity. | Read, listen to, or view local weather reports and forecasts. Discuss how to prepare and protect yourself from hazardous weather events. |
| 2. How can we measure changing weather conditions? | Weather measurements can be made by using thermometers for measuring temperature; rain gauges, for precipitation; wind vanes, for wind speed and direction; hygrometers, for humidity; and barometers, for air pressure. | Make or purchase instruments to measure changes in weather. |
| 3. What effect does sunlight have on weather? | Sunlight affects air, land, and water temperature. Sunlight affects evaporation rate. Sunlight is absorbed differently by different colors. Water and land heat at different rates. | Measure temperature differences between areas and objects in sunlight and in shade. Use different-colored cans to investigate selective absorption of energy. Experiment with heating of soil and water using a lamp. Measure temperature in various local environments. Experiment with evaporation rate. |
| 4. What effect do mountains have on weather? | Air expands and cools as it moves over mountains, which increases the chances of precipitation. Precipitation occurs more often on the side of the mountain range where the air is lifting. | Use maps, charts, and audiovisuals to discuss how mountain ranges affect weather. |
| 5. What effect do oceans have on weather? | Oceans are the source of most water vapor in the atmosphere and provide a moderating effect on temperature and climate. | Use maps, charts, and audiovisuals to discuss ocean effects on the atmosphere. |

## *Air*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***3-6*** | | |
| 6. How do changes in the seasons affect weather? | Changes in the length of the day and the angle of the Sun above the horizon cause seasonal changes in temperature, amount of precipitation, direction of wind, and type of precipitation. | Develop a class project to study the different changes in weather throughout the year. Keep track of time of sunrise and sunset at different times of the year. Observe changes in the Sun's angle above the horizon at noon during different times of the year. |
| C. What can we learn from weather records? | | |
| 1. What can be learned from weather records where we live? | Weather information collected over a period of time can show patterns. These weather patterns include temperature ranges, precipitation types, frost data, wind direction, and air quality readings. | Gather data from local meteorologists and other sources, such as the National Oceanic and Atmospheric Administration (NOAA).[2] |
| 2. What can be learned from weather patterns of various regions? | Weather information has been gathered over many years in many different areas. This information can be used to establish weather patterns. | Describe how people dress in your area compared to how people dress in different areas of the U.S. and the world. Gather and study long-term weather data from several widely separated areas. Examine similarities and differences of local weather patterns compared to other areas. |
| | Climate is a weather pattern that occurs over a long period of time in a particular region. Climate is not the same everywhere. | Study historical examples of changes in climate. Use globes, maps, and charts to find regions with climates similar to and different from the local climate. |
| D. Why do we need to be increasingly concerned about the Earth's atmosphere? | | |
| 1. Why do we need clean air? | Clean air is needed to ensure unpolluted precipitation; to maintain good health; and to provide for good visibility. | Conduct acid rain experiments. |
| 2. What can be done to provide cleaner air? | Cleaner air can be achieved by burning less materials; choosing cleaner fuels; using energy more efficiently; and practicing energy conservation. | Use audiovisuals, and discuss methods to reduce air pollution. |





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## *Air*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***3-6*** | | |
| 3. What is the greenhouse effect? | Carbon dioxide and other gases such as water vapor and methane in the lower atmosphere admit the Sun's radiation but absorb the Earth's reradiation, thus warming the lower atmosphere. This result is known as the greenhouse effect. By increasing the amount of carbon dioxide and other gases in the air through activities such as burning of fossil fuels, humans are largely responsible for the greenhouse effect possibly becoming a problem. | Do an activity to illustrate the greenhouse effect. |
| ***6-9*** | | |
| A. How can we describe the atmosphere? | | |
| 1. What is air made of? | Air contains a variety of gases, dust, and other solid particles. | Use graphs to show the relative amount of gases found in air. Demonstrate how a cloud forms and how water vapor in a closed container causes steel wool to rust. |
| 2. How does the atmosphere change with altitude? | The density and pressure of the atmosphere decreases as the altitude increases. Other characteristics of the atmosphere, such as temperature, wind speed and wind direction, and chemical composition, also change with altitude. | Study how pressure, temperature, and density change in the troposphere and stratosphere. Discuss the ozone layer and jet stream. Discuss how altimeters and barometers work. |
| B. Why does weather change? | | |
| 1. How does weather affect us? | Weather affects our personal, social, and commercial activities. | Discuss how changes in temperature, pressure, humidity, and precipitation affect us. Discuss how potentially hazardous events, such as lightning, tornadoes, and hurricanes, affect us. |
| 2. How can we observe weather? | We use a variety of techniques and instruments to observe weather. | Keep daily records of cloud types, temperature, pressure, and humidity. Use instruments such as a barometer, anemometer, and sling psychrometer. |
| 3. How can we display weather data? | Weather maps can be used to describe weather over a large or small area. | Set up a weather station. Observe TV weather reports and satellite photographs. Construct local weather maps, and study U.S. weather maps and station models. |

## *Air*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***6-9*** | | |
| 4. What causes weather to change? | Weather changes as a result of the interaction of moving air masses produced by uneven heating and cooling of the Earth's surface. Local topography and local air circulation patterns also cause weather to change. | Do laboratory activities on changes in state of water, dark and light surfaces, and heat absorption of land and water. Study different methods of heat transfer (conduction, convection, radiation). |
| 5. How can we predict changes in weather? | By observing a variety of weather conditions over time and using computer models (Numerical Weather Prediction), it is possible to establish weather patterns and to predict weather. | Practice predicting the weather, based on observation of local or regional weather data. Use U.S. weather maps to study weather systems for a few days to try to predict the weather. Do library research on the use of computer models and other technologies, such as Doppler radar, to predict weather. |
| 6. Why does weather change with the seasons? | Weather changes with the seasons because of the tilt of the Earth's axis, the revolution of the Earth around the Sun, and rotation of the Earth. These factors affect the length of days and nights and the angle of the Sun's rays on a given location throughout the year. | Set up models to show the Earth's rotation, revolution around the Sun, tilt of axis, day and night, and angle of incident sunlight. Do a laboratory activity to show that the changing angle of the Sun's rays affects the amount of energy absorbed at a given location on Earth. |
| C. How can we investigate climate? | | |
| 1. How is climate different from weather? | Weather describes the atmospheric conditions at a particular time, while climate refers to long-term weather patterns. | Investigate long-term weather patterns for different areas of state, region, U.S., and world. |
| 2. How does climate change from place to place? | A variety of factors determine the climate of a particular location. Some of these factors include latitude, elevation, ocean currents, mountain ranges, and global winds. Common factors used to define climate zones are temperature, moisture, and vegetation. | Study the effect of factors influencing climate. Investigate the climate of several continents to observe global climate patterns. |
| 3. What evidence is there that climate has changed through time? | Both physical (glacial deposits) and biological (tropical plant fossils in far northern regions) evidence show that climate has changed over long periods of time. | Study the evidence for climate change through fossils, tree rings, ice ages, and archaeology. Study local sites if possible. |

## *Air*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***6-9*** | | |
| D. How can the atmosphere be changed? | | |
| 1. How is the atmosphere changed by natural events? | A number of naturally occurring events can affect the atmosphere. These events include volcanic eruptions, forest fires, dust storms, ocean currents (El Niño), and sunspots. | Investigate how natural events affect the atmosphere. |
| 2. How do we change the atmosphere? | Humans have changed the atmosphere by burning fossil fuels and releasing gases such as chlorofluorocarbons (CFCs). The activities of plants and animals can also affect the atmosphere's composition. | Develop activities to learn about the greenhouse effect, CFCs and the ozone layer, the effects of land use and deforestation, and the combustion of fossil fuels and wood. |
| ***9-12*** | | |
| A. What are the characteristics of the atmosphere? | | |
| 1. What is the composition of the atmosphere, and what energy exchanges take place there? | The atmosphere is a mixture of gases that absorbs, transmits, reflects, and reradiates solar energy. The composition of the atmosphere has changed through geologic history. | Study the heating of buildings with solar energy. Demonstrate the greenhouse effect. Do a laboratory activity showing that the atmosphere contains oxygen, and find the relative amount of oxygen in the air. Do a laboratory activity with black and silver cans to show the differences in absorption of solar radiation. |
| 2. What is the importance of the atmosphere's layers? | The atmosphere is relatively thin compared to the Earth's dimensions and provides life on Earth with a protective shell against harmful solar radiation. The four layers of the atmosphere are defined by a temperature profile that changes with altitude. The lowest layer, the troposphere, is where most weather occurs. It also contains the gases essential to life. The layer above the troposphere, the stratosphere, contains the highest concentration of ozone. This gas effectively absorbs ultraviolet radiation from the Sun. The mesosphere and thermosphere also interact with solar radiation but have less direct effect on life than the lower layers. | Study the characteristics of the troposphere, stratosphere, mesosphere, and thermosphere. Use diagrams and charts to show the altitude and physical characteristics of these atmospheric layers. |

## *Air*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| 3. How do Earth and life cycles affect the atmosphere's composition? | The atmosphere interacts with the Earth's crust, water, and life. The chemical interaction between these spheres include the rock cycle, water cycle, oxygen cycle, carbon cycle, nitrogen cycle, and sulfur cycle. | Study the role of the atmosphere in each of the Earth's major chemical cycles. |
| B. What is weather? | | |
| 1. How is water in the atmosphere related to weather? | The physical properties of water and its abundance have significant effects on weather. Water can absorb and transfer tremendous amounts of heat energy, particularly during changes in phase during evaporation and condensation. | Do activities that show the importance of condensation nuclei and the latent heat of evaporation. Demonstrate the relationship between dew point, condensation, and relative humidity. |
| 2. What do different types of clouds indicate about weather? | Different types of clouds can be useful in studying and predicting the weather. | Study the different cloud types and how they are related to different forms of weather. Include activities that involve observing local clouds over an extended period of time. |
| 3. Where and how do low and high pressure areas develop, and what makes them rotate and travel across the Earth's surface? | Low and high pressure areas have a significant effect on weather. The rotation and transverse motion depend on their latitude and prevailing wind belts. | Study the rotational patterns of high and low pressure areas and their movement across the Earth's surface. Include the study of jet streams, the Coriolis effect, and latitudinal high and low pressure areas. |
| a. What makes the wind blow? | The wind blows as a result of differential heating, which results in differences in atmospheric pressure. | Study the Earth's system of prevailing winds and their relationship to weather patterns. See *What Makes the Wind Blow?*[3] |
| b. What changes occur at weather fronts? | Weather fronts are borders between air masses of different temperature and moisture. Changes in weather and possible precipitation are associated with weather fronts. | Select activities that use weather maps to describe weather conditions for cold, warm, occluded, and stationary fronts. |
| c. How do geographic regions and geomorphic features affect the development of pressure systems? | The development and maintenance of a pressure system is significantly affected by elevation of landforms, like mountain ranges, and the extent of surface water bodies, like the Great Lakes and oceans. | Use laboratory activity to show the differential heating rates of soil and water. Discuss orographic effects, and show how bodies of water act as heat sources and heat sinks. |

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| 4. How are weather forecasts prepared and used? | The observation, measurement, and analysis of the atmosphere are the basis for preparing weather forecasts. Recent advances in technology, such as computer modeling, enable us to make better forecasts. Weather forecasts are used in agriculture, aviation, commerce, as well as for use by the media and general population. | Make daily weather measurements over an extended period of time, and note the specific weather conditions. Practice making weather forecasts by studying past and present weather conditions. Do library research on Numerical Weather Prediction (NWP) models. Study how weather forecasts are used. |
| 5. What are atmospheric hazards? | Atmospheric conditions that require special precautions for public safety often develop . The characteristics of these weather conditions vary greatly and may be identified with seasons. | Study the weather conditions that are related to pollution, lightning, hurricanes, tornadoes, freezing rain, thunderstorms, blizzards, heavy rainstorms, microbursts, wind shear, and hail. |
| a. Under what circumstances do atmospheric hazards develop? | Atmospheric hazards, like severe thunderstorms, tornadoes, and hurricanes, are associated with the development of significant low pressure centers (cyclones). | Keep a bulletin board with newspaper clippings of weather events that resulted in atmospheric hazards. |
| b. How can we protect ourselves from atmospheric hazards? | We must be aware of the dangers involved with each type of atmospheric hazard. | Study the safety guidelines involved with weather conditions that impose a potential danger to people. Include topics such as wind chill, heat exhaustion, and hypothermia. |
| C. What is air quality? | | |
| 1. What affects air quality? | Prior to the use of fossil fuels, chemicals like chlorofluorocarbons (CFCs), and the widespread cultivation of land by humans, air quality was affected intermittently by natural phenomena, such as volcanoes, forest fires, and dust storms. | Study the various natural phenomena that affect air quality, such as volcanic eruptions, dust, pollen, evaporation, precipitation, forest fires, and organic processes. Also study human activities that affect air quality, such as industrial pollutants, combustion, including internal combustion engines, and chlorofluorocarbons (CFCs). |
| 2. What are inversions? | In typical weather conditions in the troposphere, air near the Earth's surface is warmer than air above the surface. In some cases, however, air near the surface may become cooler than air above. This inversion may be caused by cooler | Study the conditions that cause inversions. |

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| | air moving into an area or by air cooling in place. An inversion results in less mixing of air and contributes to more concentrated pollution levels. | |
| 3. How can we measure air quality? | Air quality is measured through a variety of air-sampling techniques that measure gaseous composition and particulate matter in the atmosphere. | Do laboratory activity collecting particulate matter. Check with TV stations about techniques for assessing air quality. |
| 4. How can we improve air quality? | Air quality can be improved by reducing particulate and gaseous emissions entering the atmosphere. To reduce these emissions, we need to investigate ways to conserve energy, use alternate, renewable forms of energy, and provide for clean burning of fossil fuels and waste materials. | Discuss different local and regional air quality problems. Write research paper as a proposal for improving air quality in local area. |
| D. How do we investigate climate? | | |
| 1. How are climate zones similar and different? | Climate zones can be compared by using climate classification systems based on averaging factors like precipitation, temperature, vegetation, and potential evapotranspiration. Terms like tropical, polar, humid, and arid are commonly used to describe climate zones. | Study a world map showing climate zones. Study the climate in areas similar to and different from the local area. Compare the effect of different variables on the climate of an area. |
| 2. How does climate control the geographic distribution of vegetation? | Climate controls soil types, moisture availability, and temperature, as well as the ability of crops and other vegetation to adapt to various temperatures. | Study the various crops, plants, and trees that can survive in different climates. |
| E. What careers are available in the study of the atmosphere, and what other types of employment require knowledge of this discipline? | Meteorologists gather and disseminate information about the atmosphere. Examples of others who require knowledge of the atmosphere and weather conditions are farmers, aviators, and sailors. | Invite as a guest speaker a local TV weather person or meteorologist. Discuss how weather information is used in different employment areas, such as agriculture, industry, aviation, and marine operations. |

# *Ice*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| A. Where do we find most of the Earth's ice? | Ice is found near the poles on land and in the ocean. It is also found on high mountains. | Give examples of ice and snow from your own experience.<br><br>Brainstorm where ice and snow may be found year-round. Use visual aids to show polar regions and glaciers. |
| ***3-6*** | | |
| A. What are the characteristics of ice? | | |
| 1. What happens when water freezes? | Water expands when frozen. Ice floats. Ice is a change in physical state from liquid to solid. | Measure the level of cold water in a container before and after freezing. Demonstrate that ice floats. |
| 2. How does ice form? | Ice forms at 0°C. Lake ice forms top to bottom. | Demonstrate how water freezes from top to bottom. |
| B. What are glaciers? | | |
| 1. Where are glaciers found? | Glaciers are large bodies of moving ice found on land at high latitudes and high elevations. | Use a variety of visual aids to study glaciers. |
| 2. How do glaciers affect the Earth? | Glaciers scour, scratch, move, and deposit materials of all sizes. Water from melting glaciers flows into rivers, lakes, oceans, and the ground. | Experiment with moving and melting ice in stream trays. Use maps, videos, and diagrams to contrast features found in areas of present-day glaciation. Study glaciated features of various regions of the world. |
| 3. How do icebergs form? | Icebergs are large masses of floating ice. They are formed as glaciers enter a body of water and break apart. Icebergs float with most of their mass below the water surface. | Use audiovisuals to discuss iceberg formation and hazards to ships. |
| C. What were the ice ages? | The ice ages were times of extensive glacial activity. Glaciers moved forward and melted back. Sea level changed as glaciers melted and froze. | Investigate the history of glacial periods. View audiovisuals of glaciers and glacial deposits. See *Evidence for the Ice Ages.*[1] |
| | Different life forms existed during the most recent ice age. Some life forms became extinct. | Examine pictures of extinct life forms, such as mammoths and mastodons. List extinct life forms. |

## *Ice*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| *3-6* | | |
| | Ice ages have occurred in different parts of the Earth at different times. | |
| *6-9* | | |
| A. How does ice occur on Earth? | | |
| 1. Where is ice found? | Ice is found on the Earth in a variety of conditions and locations. Year-round ice is found in high latitudes near the poles and at high elevations at other latitudes. | Use maps and globes to study ice in the Arctic, Antarctic, and alpine regions of the Earth. |
| 2. What forms does ice take? | Ice occurs as glaciers, icebergs, sea ice, and ice in permanently frozen ground. | Develop activities to help understand permafrost, glaciers, sea ice, icebergs, and snow fields. |
| B. How can we investigate glaciers? | | |
| 1. How do glaciers form? | A glacier forms from the accumulation of large masses of snow. Continual accumulation and compaction of this snow forms ice, which moves under its own weight. The extent to which glaciers form depends upon climate. | Study how recrystallization of snow, gravity, and climate affect the formation of glaciers. |
| 2. How do glaciers move? | Glaciers move as a result of gravity. The greater the thickness and slope of a glacier, the faster it can move. | Demonstrate Silly Putty on a slope. Study the rate of movement, flow, wasting, and equilibrium of glaciers. |
| C. How do glaciers change the Earth? | | |
| 1. What happens when a glacier advances? | As a glacier advances, it can create a variety of landforms through erosion and deposition. | Use field trips, audiovisuals, and models to show how glaciers can produce U-shaped valleys, cirques, moraines, striations, and drumlins. |
| 2. What happens when a glacier melts? | Melting glaciers leave deposits and produce or affect water systems. | Use field trips and audiovisuals to show moraines, meltwater, outwash, and lakes produced by melting glaciers. |
| 3. What is the evidence that ice ages have occurred? | Scientific evidence, such as glacial deposits and landforms, and data collected from archaeological sites show that continental glaciers have covered large regions of the Earth and have changed sea level at different times in the past. | Study the evidence of ice ages in texts or audiovisuals. |

## *Ice*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***6-9*** | | |
| D. What resources result from glaciation? | Glaciation has produced a variety of resources that we use. These resources include soils, sands, and gravels, as well as lakes and ground-water aquifers. | Study local features related to glaciation. Study the effects of glaciation on the production of sand, gravel, and soils. |
| ***9-12*** | | |
| A. How does year-round ice affect the Earth's surface? | | |
| 1. What causes ice to flow? | As thick masses of ice (glaciers) accumulate (thousands of feet) on land, they will move either downslope or outwardly by plastic-like flow of the ice and slippage due to water in the ice. | Study the properties of ice, and experiment with ice deformation. Research the conditions prevailing at the surface, the interior, and the base of an ice sheet. Introduce stress-strain diagrams to illustrate changes in ice under pressure. Explore influence of temperature, thickness, ground shape, and roughness on glacial movement. Supplement discussions with slides and films. |
| 2. How does the movement of glaciers affect the surface over which they flow? | Movement of glaciers over land surfaces results in the formation of characteristic erosional and depositional features. | Use visuals to illustrate unique effects of glacial erosion in mountainous and non-mountainous terrain. Show and discuss effects of ice-deposited features. Study maps of glaciated regions. |
| 3. What are some surface effects of permafrost? | In areas of permafrost, uniquely patterned grounds, ice mounds and wedges, thaw basins, and soil flows are found. | Research permafrost, and illustrate surface features with slides or movies. |
| B. How can the cryosphere change over time? | | |
| 1. What would cause the amount of year-round ice to decrease or increase? | Long-term changes in solar radiation reaching the Earth's surface (insolation) would alter the volume of year-round ice. Changes in the volume of glacial ice would result in global changes in sea level, weather patterns, and climate. | Discuss possible causes for variations in insolation sufficient to result in increase or decrease of year-round ice. Discuss volcanic dust, and determine if a correlation can be made between prolific eruptions and changes in the cryosphere. Experiment with effect of dust on heating of atmosphere. Study effects of variation in atmospheric gases and reasons for their variation (i.e., greenhouse effect). |

## *Ice*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| 2. How might human activity affect the cryosphere? | Expanded development, industrialization, and technologies can result in global atmospheric changes that can alter the Earth's cryosphere. | Discuss human processes or practices that might contribute to a change in the volume of the cryosphere. Use articles and movies to emphasize those activities. Consider influence of tropical deforestation, dust particulates, and greenhouse effect. Use comparison of Mars and Venus. |
| C. How did the most recent ice age affect the Earth? | | |
| 1. How did the most recent ice age modify the Earth's topography and drainage? | Advances of ice sheets during the Pleistocene caused large surface areas to be modified by erosional gouging and general abrasion, whereas in the marginal zones of thinning ice, large volumes of sediment were deposited. Both processes produced dramatic effects upon the land and its surface drainage. | Use a modern geomorphology textbook as a sourcebook. Examine topographic maps, high altitude photographs, and satellite images of glaciated areas. Use diagrams, models, and films employing animation to illustrate changes produced by glaciers to the land surface. Discuss formation of the Great Lakes. |
| 2. How did the most recent ice age affect the types and distribution of life? | During the most recent ice age, vegetation belts shifted southward, and animal and human migration occurred. | Reconstruct events of the most recent ice age. Using anthropology text as sourcebook, discuss human migration. |
| 3. What resources resulted from the most recent ice age? | Many non-metallic deposits were produced as a direct product of glacial advances during the most recent ice age. | Do library research on glacial resources, such as sand, gravel, peat, lakes, and aquifers. Plot resources on maps, and determine if any correlate with known glacial features. |
| D. How can we learn about past climates by studying year-round ice? | By investigating layers of ice (ice stratigraphy), we can learn about past climates. Entrapped pollens, volcanic dust, and gases found in the layers can imply the atmosphere's temperature and composition in the past. | Study ways that layers of ice can yield past environmental characteristics. |
| E. How and by whom should Antarctica be managed? | There are significant problems in determining territorial claims and jurisdiction in using the resources of Antarctica, the continent containing the largest ice sheet in the world. | Use U.N. publications as sources of information regarding managing Antarctica's resources. Debate on issues identified. |
| F. What hazards are associated with the cryosphere? | The cryosphere provides potential hazards on land and in the oceans. | Use the Titanic to introduce hazards from glacial calving, which |

## *Ice*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| *9-12* | | |
| | Widespread melting of the Earth's glaciers and snow fields would cause worldwide rise of sea level. Widespread accumulation of ice would cause glaciers to spread over land now occupied by humans. | produces icebergs, and to stimulate interest. Experiment with large ice blocks in salt water. Research newspapers and magazines for glacier-associated problems, (e.g., avalanches). Use maps of coastlines and high latitudes to study how changes in the sea level and ice masses could inundate the land. Consider global demographic and economic impact. |
| G. What kinds of technology are used to study the cryosphere? | A variety of scientific technological applications are used in the study of the cryosphere. One of the most productive is coring. | Assign reports exploring ways ice is studied. Invite guest speakers to discuss special problems in conducting research on the cryosphere, techniques of coring, and use of microwave techniques. |
| H. What careers are available in the study of the cryosphere, and what other types of employment require knowledge of this discipline? | Glaciologists study the physical properties and movements of the cryosphere. Examples of other professions that require knowledge of the cryosphere are civil engineering, construction, farming, architecture, real estate, and land use planning. | Compile a list of professions that study ice masses and the influence of the cryosphere on human activity and wildlife. Invite professionals to speak on their experiences. |

# *Life*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| A. What clues do we have that plants and animals lived long ago? | | |
| 1. What are fossils? | Fossils are the remains of plants and animals that lived long ago.<br><br>Fossils teach us what the Earth was like in the past. | Hand out fossil specimens. Draw pictures and describe. Generate a list of properties of the fossils (shape, size, color, texture). Discuss where each living thing that became fossilized could have lived.<br><br>Define what a fossil is. Use clay or plaster of Paris and a shell to make a fossil imprint. |
| 2. What were dinosaurs, and what happened to them? | Dinosaurs were animals that lived millions of years ago.<br><br>No dinosaurs are alive today. Scientists have several ideas as to why dinosaurs became extinct. | Use bones to discuss clues that help us figure out what dinosaurs were like. Compare different-sized bones (e.g., thigh bone from chicken and cow) to infer the size of the animal. Examine and measure a dinosaur foot impression. Describe the foot that made the footprint. Draw the body length of various dinosaurs. Draw dinosaur teeth; infer what a dinosaur's diet was. Discuss what might have happened to dinosaurs to make them extinct. |
| ***3-6*** | | |
| A. How does life use the Earth? | | |
| 1. What is necessary for life on Earth? | Air, water, sunlight, and nutrients are essential to life on Earth. | Do investigations with lichens and algae in high and low temperature conditions. Study plant growth in environments where essentials for life are removed. Build and maintain a terrarium.<br><br>Compare habitats and the methods by which living things get what they need to survive. |
| 2. How is the Earth used by humans? | Humans use the Earth for food, shelter, energy resources, recreation, waste products, metal resources, and non-metal resources. | Explore past and present uses of the Earth. |

| *Life*<br>*Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| *3-6* | | |
| B. Why have some living things become extinct during prehistoric and historic times? | Some changes in habitat are so severe that they cause extinction. Changes in habitat can be produced by climate. Changes in habitat can be produced by humans. | Experiment with the students' perceptions of heat and cold, breathing, confinement and crowding, and other factors that can give insight into the ways in which living things adapt or do not adapt to their environments. |
| C. How do we affect the habitat of other living things? | Humans affect habitats by changing patterns of land use. Humans affect habitats by adding to the habitat new chemicals, such as pesticides and other solid, liquid, and gaseous waste products. | Examine local areas for changes in land use and for pollution effects caused by humans. |
| D. What actions can we take to show concern for life on Earth? | Humans can show concern by cleaning up the community, recycling, using Earth materials wisely, changing wasteful buying habits, protecting natural areas, and understanding more about the Earth's problems. | Research endangered habitats. Select a service project, such as keeping the school or community clean. |
| *6-9* | | |
| A. How does the Earth support life? | | |
| 1. What materials and conditions support life on Earth? | In general, plant and animal life on Earth need water; adequate temperature range; energy supplied directly from the Sun or indirectly through other life forms; oxygen and carbon dioxide from the atmosphere; and nutrients from soils. | Discuss what certain plants and animals need in the Earth's water, atmosphere, and crust. |
| 2. Why isn't life the same everywhere? | Specific geographic conditions, like climate, soils, elevation, geology, and latitude, determine the types of plants and animals that are native to a particular area. | Use maps to study how plant and animal populations in different regions are affected by geographic factors. |
| B. How have life and the Earth changed? | | |
| 1. How do we know living things have changed through time? | The fossil record shows that plants and animals have changed over long periods of time. | Use activities to learn about fossil classification and fossil identification and correlation over time. |

## *Life*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***6-9*** | | |
| 2. How can fossils reveal the past? | The study of fossils can tell us about environments in which plants and animals lived in the past. | Study paleoenvironments (e.g., terrestrial-marine), and compare with modern environments. |
| 3. How have living things changed the Earth? | Living things have changed through geologic time the composition of the Earth's air, oceans, and crust. | Discuss the effects of living things on soils, atmosphere, oceans, rivers, and lakes. Study how living things have created natural resources, like fossil fuels, limestone, and iron. |
| 4. How does the way we live affect living things? | Human activity, such as industrialization, urbanization, and agriculture, can significantly affect the land, soil, water, and air that plants and animals need to live. | Study the impact of humans on the local and global environment. Include ideas like population growth, resource development, and sustainable development. |
| ***9-12*** | | |
| A. What do fossils reveal about the past? | | |
| 1. How do fossils reveal information about the environment in which the organisms lived? | Fossils reveal information such as how (meat-eaters or plant-eaters) and where (marine or terrestrial) the organisms lived; their physical structures (vertebrate or invertebrate); anatomical features (e. g., teeth); and chemical composition (e. g., shells). | Work with a good fossil collection. Compare shell fossils with modern forms of shells. Use laboratory problems that require environmental interpretations and evaluations of changes through time by stratigraphic analysis. Determine characteristics of marine organisms in high and low energy zones, light and dark environments, and warm and cold waters. Compare land and marine forms. |
| 2. What do fossils reveal about major geographic and environmental changes throughout geologic history? | The study of fossils and their distribution provides information on water temperatures, depths, and composition (fresh or marine), and contributes to our understanding of paleogeography and the changes that have taken place during the Earth's history. | Research and plot locations of several fossils and the rock age in which they were found. Interpret the past environment (paleogeography) from your observations. Observe climatic variations through time. |
| 3. How do fossils provide evidence for organic evolution? | The succession of fossil assemblages in the stratigraphic column provides insight into the changes in life forms through exceedingly long intervals of time. | Discuss and do laboratory activities to investigate changes in life forms from simple to increasingly complex and varied. Emphasize that changes are the norm and may be abrupt or gradual. Illustrate with studies of extinctions. Discuss concepts and use of index fossils. |

| *Life*<br>*Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| B. How do Earth materials support food webs? | Rock-derived soils contribute the soluble nutrients necessary for plant growth on land; in marine environments, plant and animal life depends upon dissolved nutrients in the photic zone. The nutrients are derived from deeper waters largely by the process of upwelling. | Highlight the importance of the food web by having panel or series of short talks by soil scientists, biologists, and agronomists. |
| C. How are we responsible for all remaining living things? | We have disproportionately great influence on virtually all other life forms because we can drastically alter the environments upon which all life forms depend. | Use audiovisuals to study environmental problems. Consider changes that have occurred on Earth and their probable impact. Hold debates and discussions on topical environmental issues. |
| D. How has technology enabled us to extend our habitable environment? | Human habitation has expanded into formerly hostile environments because of technological developments, which help us control such factors as energy, air, water, shelter, and agriculture. | Study how technology is used to transport fuel, water, goods, and services and to manage enclosed environments. Investigate or visit Biosphere 2.[1] |
| E. What careers are available in the study of the Earth's interaction with the biosphere, and what other types of employment require knowledge of this discipline? | Geoscientists, meteorologists, oceanographers, and biologists study interactions of the biosphere with the other Earth spheres. | Develop a list of professions that must know "all sphere" interactions. Invite local representatives to speak to class. Compile a career report. |

# *Earth in Space*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| A. How are the Earth, Moon, and Sun alike and different? | | |
| 1. How does the Sun's position change during the day? | The Sun, which provides Earth's heat and light, is at different positions in the sky at different times of the day. The Sun appears to move across the sky from east to west. | To study the effect of the Sun on the Earth, compare the melting rate of an ice cube in sunlight and in shade.<br><br>Study the shadow of the school flagpole. Observe and measure the shadow at different times of the day. When is the shadow the shortest and longest? What direction does the shadow point in relation to the Sun? What path does the Sun appear to take?<br><br>Study how a sundial works. Mount a dowel perpendicular to a piece of cardboard. Every hour draw a shadow. |
| 2. What causes day and night? | The Sun rises at the beginning of the day and sets at the beginning of the night. This rising and setting is due to the rotation of the Earth. | Over a period of time, observe changes in the length of day and night by recording time of sunrise and sunset. |
| 3. What can we see in the day sky and in the night sky? | Sometimes the Moon can be seen at night, and sometimes it can be seen during the day. Planets can sometimes be observed in the evening or early morning skies. The Moon and planets reflect the light of the Sun. Stars can be seen in the evening sky. Stars, like the Sun, produce their own light and heat. | Observe the sky. Depending on the season, you will be able to see Venus, Mars, Jupiter, and Saturn in the early morning, early evening, and night sky. Refer to *Science and Children*,[1] a journal that has a section on the night sky and lists visible planets. At sunrise and sunset the brightest objects are frequently the planets. |
| 4. How does the Moon appear to change? | The Moon's apparent shape changes daily. The Moon appears to move across the sky from east to west daily. The Moon's position in the sky in relation to the stars and Sun changes daily. We can only see the sunlit part of the Moon. The Moon reflects light from the Sun. | Pick a time each day (or night) and a constant place to stand to look at the Moon. Observe how it changes position and shape. You can measure the change in height above the horizon by using your outstretched fist as a measuring device. Demonstrate how to keep your arm level with the bottom of your outstretched fist on the horizon. Changes in the Moon's position can be measured by standing in the |

## *Earth in Space*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***K-3*** | | |
| | | same place during each observation and comparing the Moon's position to a common reference point, like a tree or roof. Observe these changes over a period of a month. What shape does the Moon have when it is out during the day compared to when it is out at night? Use a chart to record your observations. How many days are there from full moon to half moon, half moon to new moon (no moon), new moon to half moon, and back to full moon? Predict the shape of the Moon, and verify your predictions. |
| | | Teacher note: Children often believe incorrectly that the phases of the Moon are caused by a shadow created by the Earth. The phases are due to the relationship between the Earth, Moon, and Sun. The Moon reflects the light from the Sun. Because the Moon revolves around the Earth, a person looking at the Moon sees the illuminated portion of the Moon from a different angle each night. |
| ***3-6*** | | |
| A. What can we see in the sky? | | |
| 1. What can we see in the day sky? | During the day, we can see the Sun, Moon, and sometimes other bright objects. | Observe the daytime sky over an extended period of time, and note the relative position of the Sun and Moon. |
| 2. How does the Sun appear to move in the sky? | The Sun appears to move across the sky in a semicircular motion from east to west. | Observe and record the apparent path of the Sun, and chart the times and direction of rising and setting and the maximum altitudes over an extended period of time. |
| 3. What can we see in the night sky? | During the night (with the unaided eye, binoculars, or telescope), we can see stars, the Moon, planets and their moons, meteors, and man-made satellites. | Observe the night sky, and record observations over an extended period of time. List objects observed, and compare with photographs. |

## *Earth in Space*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***3-6*** | | |
| 4. How does the night sky change? | During one night, the objects in the sky appear to move in a circular motion around the North Star. From night to night, the stars appear to shift westward, the Moon's shape and position change, and the planets appear to wander. | Observe and record changes in the phases of the Moon and its position in the sky over a period of at least 30 days. |
| B. How are the Earth, Moon, and Sun related? | | |
| 1. How can the sizes of the Earth, Moon, and Sun be compared? | The Sun is much larger than the Earth and Moon. The distance between the Sun and Earth is much greater than that between the Earth and Moon. Because of the Sun's great size and distance from the Earth, it appears to be the same size as the Moon. | Draw scale models to show relative sizes and distances. Create scale models of the Sun, Earth, and Moon. Observe objects of various sizes at different distances. |
| 2. In what ways do the Earth and Moon move in relation to the Sun? | The Moon revolves around the Earth. The Earth and Moon revolve around the Sun. The Earth and Moon rotate while revolving around the Sun. The period of the Moon's rotation is the same as a lunar month. | Create simulations of Earth, Moon, and Sun motions using spherical objects carried by students. Investigate day and night with flashlight and sphere. |
| 3. Why is the Sun considered the Earth's most important energy source? | The Sun provides heat and light energy. Solar energy controls weather and climate. Through the process of photosynthesis, solar energy is stored in plants. It is passed through the food chain to all forms of animals, including humans. Through this process, solar energy is also stored in fossil fuels, such as coal, oil, and gas. | Discuss changes that can occur if the energy from the Sun increased or decreased. Study variation in daytime and nightime temperatures and seasonal temperature changes. |
| C. How is the Earth-Moon-Sun system related to other objects in the Solar System? | | |
| 1. What are the members of the Solar System? | Members of the Solar System include the Sun, Moon, planets, their moons, comets, and asteroids. | Visit a planetarium. Examine National Aeronautics and Space Administration (NASA) photographs.[2] Study the various members of the Solar System. |
| 2. Where are the Earth, Moon, and Sun located in the Solar System? | The Sun is at the center of the Solar System with the planets and other objects of the Solar System | Make a model of the Solar System. |

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***3-6*** | | |
| | revolving around it. The Earth's and Moon's orbits are about 93 million miles (150 million km) out from the Sun. | |
| D. What can we learn from space exploration? | | |
| 1. What have we learned about the Earth and Moon from space? | Satellites and space probes observe and measure the Earth's and Moon's features and structures on a planetary scale. Satellites send back images of the Earth's weather patterns, ocean circulation, and landforms. | Examine NASA photographs to study Earth's landforms, ocean circulation, and large weather systems. Show how space exploration has been used to develop new ways to solve problems. |
| 2. What benefits to humanity result from space exploration? | Benefits from exploration of space include medical and technological advancements, such as electronic miniaturization and lightweight yet strong plastics and metals. | Study NASA publications to learn about technological and medical advancements. |
| 3. How do we learn about the Solar System? | Exploration is conducted with the use of telescopes, satellites (manned and unmanned), and space probes. | Study a variety of resources that illustrate images of Earth and other Solar System objects. |
| 4. What have we learned about the Solar System from space exploration? | Space exploration has shown many new and interesting features of the planets and moons in the Solar System. Some examples are the great canyon (Valles Marineris) and volcanoes (Arsia Mons, Olympus Mons) of Mars; Great Red Spot of Jupiter; sulfur lava flow on Io; and the "chevron" figure on Miranda's surface. | Study NASA publications, photographs, tapes, and other resources. |
| 5. What are the possibilities for life on other planets? | If conditions necessary for life, such as moderate temperature, water, oxygen, carbon dioxide, and minerals, exist on other planets, life could exist on those planets. | Design an imaginary trip to the Moon. Discuss the problems of living in a hostile environment. |
| ***6-9*** | | |
| A. How can we observe objects in the sky? | | |
| 1. What can we see without a telescope? | Without a telescope, the Sun, Moon, stars, comets, planets, meteors, and artificial satellites can be seen. | Observe the Sun, Moon, stars, comets (if possible), meteors, artificial satellites, and planets. Use audiovisuals; observe a few constellations. |

## *Earth in Space*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***6-9*** | | |
| 2. What can we see with a telescope? | Binoculars and optical telescopes extend the ranges of normal vision to observe galaxies and moons of other planets. | Use binoculars and telescopes to observe the Moon, stars, planets and their moons, galaxies, and nebulae. Sketch the Moon. |
| 3. How can we observe objects in the sky in other ways? | A variety of other instruments, such as radiotelescopes and space-based telescopes, are used to learn more about the structure of the Universe. | Study the electromagnetic spectra and spectroscopes. Read about satellite imagery, astrophotography, and radiotelescopes. Use audio-visuals. |
| B. What are the motions of objects we see in the sky? | | |
| 1. How do celestial objects move through the sky? | The Sun, Moon, planets, and most of the stars appear to move daily across the sky from east to west. The exceptions to this east-to-west movement are meteorites and artificial satellites. | Observe rising and setting motions of Sun, Moon, stars, and planets. Observe the Sun's path, using a shadow stick. Transparent plastic hemispheres, available from suppliers, can be used to track the Sun's path. |
| 2. Why do celestial objects appear to move around the Earth? | Celestial objects appear to move around the Earth because of the Earth's rotation. The Sun, Moon, and planets appear to drift among the stars because of the revolution of the Earth around the Sun. | Use models to show the eastward drift of the Sun and Moon. |
| 3. How do actual motions of objects in the Solar System affect us? | The rotation and revolution of the Earth, along with the tilt of the Earth on its axis, cause day, night, and the seasons. The motions of the Moon and Earth cause tides, the phases of the Moon, and eclipses. | Use models, graphs, and photographs to learn about tides, seasons, day and night, eclipses, phases of the moon, asteroids, comets, and meteorites. Study Foucault pendulum and Coriolis effect. |
| C. What kinds of objects exist in space? | | |
| 1. What is the Sun? | The Sun is an average star in the Milky Way galaxy. It is constantly changing. | Use activity with models to develop size and distance relationships among the Sun, Moon, and Earth. Learn about fusion, electromagnetic radiation, and speed of light. |
| 2. How do changes on the Sun affect us? | Electromagnetic storms on the Sun cause sunspots. These storms also cause particles from the Sun to interact with Earth's atmosphere to produce phenomena such as the aurora borealis. | Study the effect of sunspots on radio transmission and Earth's magnetic field. |

## *Earth in Space*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***6-9*** | | |
| 3. How does the Earth compare with other objects in the Solar System? | When compared to the Earth, there is significant variation in the size of planets and their moons, their distance from the Sun, and their composition. | Compare the size, distance, composition, features, and surface temperatures of the planets. |
| 4. What kinds of objects exist outside the Solar System? | Other galaxies and phenomena related to those galaxies (e.g., black holes, pulsars, quasars) are outside the Solar System. | Read about different types of galaxies, black holes, pulsars, and quasars. Use photographs when possible. |
| D. How can we use space? | | |
| 1. How can we live in space? | Space vehicles need to provide certain conditions for humans to live in space. | Study the physical conditions provided by a space shuttle and future space stations. Design a space habitat. |
| 2. What can we learn about the Earth from space? | We have learned a great deal about the Earth's air, water, ice, life, and crust as a result of artificial satellites. | Study information from space photographs and remote sensing data that show Earth features, including Earth's shape. Discuss how satellites are used to predict weather and track storms. |
| 3. How has space technology changed our lives? | Space technology has affected the development of many new products on Earth, particularly in the area of communications. | Study the ways that space technology has been applied to modern living. Use information from NASA. Discuss possible military aspects of using space travel. |
| E. How is the Universe changing? | | |
| 1. How did the Universe begin? | At the present time, the "big-bang" theory is the most widely accepted theory to explain how the Universe may have begun. The theory is based on the observation that galaxies, the largest structures in the Universe, seem to be moving away from each other. | Discuss various theories of the evolving Universe. Use appropriate audiovisuals. |
| 2. How can we measure the Universe? | Observations made through use of instruments like spectroscopes and radiotelescopes help us learn more about the structure of the changing Universe. | Study the evidence of the expanding Universe (Doppler red shift). Discuss scale as it applies to the study of galaxies. Use Nerf football demonstration to show Doppler effect: insert bell, buzzer, or horn inside football, and throw football across the room. |



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## *Earth in Space*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***6-9*** | | |
| 3. Will the Universe end? | It is not possible to know all there is to know about the Universe with our present technology. | Discuss changes that have taken place through the years in our view of the Universe. |
| ***9-12*** | | |
| A. What is the setting of the Earth in the Solar System? | | |
| 1. What objects are in the Solar System? | The Solar System includes the Sun, planets with their moons and planetary rings, comets, asteroids, and meteors. | Do activities that show the various components of the Solar System and how we learn about these components. |
| 2. Why is the Earth unique compared with other Solar System objects? | As a planet in the Solar System, the Earth has some unique features that include liquid water, plant and animal life, large Moon, and atmosphere with mostly nitrogen and oxygen. | Study the similarities between the Earth and the other planets (and their moons). |
| 3. How and when was the Solar System formed? | The nebular theory states that the Solar System began as a large cloud of gas and dust called a nebula about five billion years ago. | Study the various theories of the Solar System that have been developed. Discuss the flaws in these theories. Use diagrams and films to learn about the evolution of the Sun and planets. |
| B. What is the setting of the Solar System in the Universe? | | |
| 1. How far apart are objects in space? | The distances between objects in the Solar System and galaxy are so great that they have to be measured through indirect techniques. | Learn about astronomical units, light years, and parsecs. Calculate the length of time it takes for light to travel between objects in the Solar System and in the Milky Way galaxy. |
| 2. How does the Solar System move relative to the Milky Way galaxy? | The Solar System is part of a large system of stars called the Milky Way galaxy. The Solar System revolves around the center of the galaxy. | Use visual aids to study the approximate location of the Solar System in the galaxy. Determine the time, distance, and velocity for one revolution. |
| 3. How can we look backward in time by looking into space? | Because of the vast distances in the Universe, the light reaching our eyes and instruments from distant objects is millions of years old. Thus, our present view is actually a view of history. | Show how the Doppler effect is used to study relative motion. |

## *Earth in Space*

| *Essential Questions* | *Key Ideas* | *Seeking Answers* |
|---|---|---|
| ***9-12*** | | |
| 4. What is the probability that life exists elsewhere in the Universe? | The large number of stars in the Universe increases the probability that there is life elsewhere. Other forms of life may exist. | Use the Hertzsprung-Russell diagram (H-R diagram) to study theories of stellar evolution. Discuss the frequency of stars similar to the Sun and the possibility and probability of other planets similar to the Earth. |
| 5. How can people live beyond the Earth's atmosphere? | To live beyond the atmosphere, people need to create an artificial environment similar to the conditions near the Earth's surface. | List and discuss the components necessary for life to exist in an artificial environment. Use information from NASA to discuss human survival needs on the Moon and Mars. Simulate Mars landing. |
| 6. How is the Universe changing? | The Universe has been expanding, with the galaxies moving farther apart, for billions of years. | Study galactic evolution and the evidence of the expanding universe. Discuss the similarities and differences among the different galaxies found in the Universe, and compare other galaxies to the Milky Way. |
| C. What tools and technology can we use to extend our senses to study space? | Space vehicles, such as Voyager, have helped us understand various aspects of the Solar System, such as magnetic fields, planetary rings and moons, rates of rotation, and differences in composition of planetary bodies. Optical, radio, and orbiting telescopes extend our ability to observe objects beyond the Solar System. | Use the resources of the NASA Education Centers to conduct appropriate activities.[3] Study the ideas learned from the various probes in the Solar System by artificial satellites. |
| D. What careers are available in the study of the Earth and the Solar System, and what other types of employment require knowledge of this discipline? | Jobs in the aerospace industry, medicine, geology, planetary science, astronomy, and many others require some knowledge of the Earth in space. | Use NASA materials and other teaching resources to discuss career opportunities in the study of space and space technology. |

## *Solid Earth*

1. *Earthquakes: A Teacher's Package for K-6* (Washington, D.C.: Federal Emergency Management Agency, Earthquake Programs). Developed by the National Science Teachers Association with support from FEMA. One free copy per school is available.

2. *Reflections in Time*, from the AGI/EBE Earth Science Program (Chicago: Encyclopaedia Britannica Educational Corp.), 16mm, video.

3. *The Earth Has A History* (Boulder: Geological Society of America), video.

4. Gene Hinman, "Determining the Earth's Circumference," in *Earth Science Investigations*, edited by Margaret A. Oosterman and Mark T. Schmidt (Alexandria: American Geological Institute, 1990), 159-163.

5. American Geological Institute, "Investigating the Size of the Earth," in *Investigating the Earth*, 4th ed. (Boston: Houghton Mifflin Co., 1987), 18-19. Prepared by William H. Matthews III et al. Sponsored by the American Geological Institute and based on the original Earth Science Curriculum Project.

6. *Erosion: Leveling the Land*, from the AGI/EBE Earth Science Program (Chicago: Encyclopaedia Britannica Educational Corp.), 16mm, video.

7. *Why Do We Still Have Mountains?* from the AGI/EBE Earth Science Program (Chicago: Encyclopaedia Britannica Educational Corp.), 16mm, video.

8. California Department of Conservation, Division of Oil and Gas, Sacramento, CA 95814.

9. Hinman, "Determining the Earth's Circumference," in *Earth Science Investigations*, 159-163.

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11. Crustal Evolution Education Project (Rochester: Wards Natural Science Establishment, 1979). Developed by the National Association of Geology Teachers.

12. James H. Shea, "The Earth's Magnetic Field: Reversals of Direction," 188-195; James H. Shea, "Magnetic Intensity Anomalies and Sea-Floor Spreading," 196-205, in *Laboratory Manual in Physical Geology*, 2nd ed., edited by Richard M. Busch (New York: Macmillan Publishing Co., 1990). Produced under the auspices of the American Geological Institute and the National Association of Geology Teachers.

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1. Ezra Jack Keats, *Snowy Day* (Bergenfield, NJ: Penguin USA, 1962).

2. American Geological Institute, "Investigating the Movement of Water in Soil and Rock," in *Investigating the Earth*, 104-105.

3. *What Makes the Wind Blow?* from the AGI/EBE Earth Science Program (Chicago: Encyclopaedia Britannica Educational Corp.), 16mm, video.

***Air***

1. Federal Emergency Management Agency (headquarters), Earthquake Program, 500 C Street, S.W., Washington, D.C. 20472.

2. National Oceanic and Atmospheric Administration, National Climatic Center, Federal Building, Ashville, NC 28801.

3. *What Makes the Wind Blow?* from the AGI/EBE Earth Science Program (Chicago: Encyclopaedia Britannica Educational Corp.), 16mm, video.

***Ice***

1. *Evidence for the Ice Ages*, from the AGI/EBE Earth Science Program (Chicago: Encyclopaedia Britannica Educational Corp.), 16mm, video.

2. United Nations Information Center, 1889 F Street, N.W., Washington, D.C. 20006.

***Life***

1. Biosphere 2 Giftshop, P.O. Box 689, Oracle, AZ 85623.

***Earth in Space***

1. National Science Teachers Association, *Science and Children* (Washington, D.C.: National Science Teachers Association).

2. NASA Central Operation of Resources for Educators, Lorain County Joint Vocational School, 15181 Route 58 South, Oberlin, OH 44074.

3. Ibid.

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